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JOURNAL OF THE
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Volume 4 OCTOBER, 1937 Number 12

The Torsional Critical Speeds of Geared Airplane Engines

J. P. DEN HARTOG and J. P. BUTTERFIELD, *Harvard University**

(Received July 7, 1937)

SUMMARY

An analysis of the effect of gears on the torsional critical speed of an engine. Fig. 1 shows the percentage deviation caused by this effect. For stiff engine mounts the shaft critical speed is lowered, while for very flexible mounts that critical is raised by the action of the gears. These deviations may be as much as 15 percent either way.

TORSIONAL vibrations of the rotating parts of a direct drive, non-geared, radial airplane engine are practically without reaction to the stationary cylinders, so that for a calculation of the critical speed only the inertia and stiffness characteristics of the propeller-shaft-piston assembly are of importance. The cylinder assembly is attached to the fuselage through a mount of some torsional flexibility, which gives rise to another, totally different, critical speed whereby the non-rotating part of the engine vibrates torsionally with respect to the fuselage. For the calculation of this critical the elastic and mass-properties of the cylinders and mount only are to be considered, so that the total problem of torsional vibration falls apart into two separate single-degree-of-freedom systems which are practically not coupled to each other.

This statement is no longer generally true for geared engines, because there the two motions become "coupled," which can be understood as follows. If the rotating part vibrates torsionally, the gear tooth pressure varies periodically and the reactions of the tooth pressure on the gear and on the pinion are taken by the bearings of the propeller and crank shafts. These bearings are built into the cylinder block, and the two reactions, being equal and opposite forces, exert a torque on the cylinder block. Thus a vibration of the "shaft" causes a vibration of the "frame." On the other hand, if the frame turns through an angle, the gears have to roll over each other which causes torsion in the shafts. This is true for spur gears as well as for planetary gear systems.

The existence of this effect has been known for some time, and it has been held responsible for the discrepancies between observed critical speeds and those calculated without this coupling effect. A rough rule was established empirically stating that "the coupling effect reduces the critical speed to an amount that may be as high as 15 percent."

The mathematical analysis of this problem, as given below, though not difficult, becomes rather cumbersome, but its main result can be interpreted in a rather simple manner by referring everything to the two "uncoupled" criticals, that is to the "shaft" critical speed and the "frame" critical speed, each calculated by the old method assuming no gear effect. The analysis then leads to the conclusion that in the actual, coupled, system there are two critical speeds, of which one is smaller than the smallest of the two uncoupled speeds and the other is greater than the greatest uncoupled speed. In one sentence: *The gear coupling effect spreads the two critical speeds farther*

* The authors are indebted to C. Fayette Taylor of the Massachusetts Institute of Technology for calling this problem to their attention.

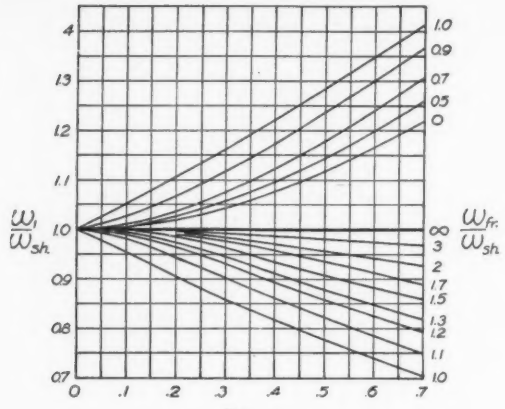


FIG. 1.

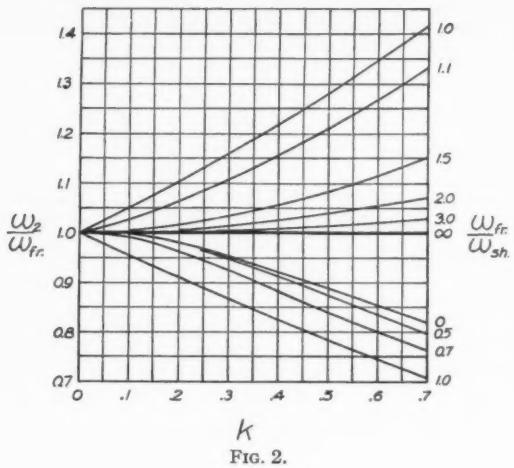


FIG. 2.

apart. For practical computation the results of the analysis are given in Figs. 1 and 2. The steps in their application are as follows:

(1) Calculate the "shaft" critical in the usual way (assuming no coupling) with the formula

$$\frac{\pi}{30}\,(\text{r.p.m.})_{shaft} = \omega_{shaft} = \sqrt{\frac{k_{shaft}}{I_{shaft}}} = \sqrt{\frac{1/I_{shaft}}{1/k_{shaft}}} = \sqrt{\frac{\dfrac{1}{I_{crank}} + \dfrac{1}{p^2 I_{prop.}}}{\dfrac{1}{k_2} + \dfrac{1}{p^2 k_1} + \dfrac{(1-p)^2}{p^2 k_4}}} \qquad \text{(a)}$$

in which I's are moments of inertia in lbs.in.sec.^{2}, k's are stiffnesses in in.lbs./radian (as shown in Figs. 3 and 4) and p is the ratio of the propeller and engine speeds. This ratio p is usually smaller than one; for spur gears it is negative: $p = -r_2/r_1$, while for a planetary system it is positive $p = R/R + r$. For a 2 to 1 planetary system the arrangement of Fig. 4 is replaced by bevel gears, but the analysis still holds; the formulas may be applied with $p = 0.5$. The last term in the denominator of Eq. (a) comes in only if the central sun gear of the planetary system is coupled to the frame with some flexibility. In most constructions this coupling is stiff and in such cases $k_4 = \infty$ and the term simply disappears.

(2) Calculate (or estimate) the "frame" critical:

$$\frac{\pi}{30}\,(\text{r.p.m.})_{frame} = \omega_{frame} = \sqrt{\frac{k_{mount}}{I_{cyl.}}} \qquad \text{(b)}$$

in which $I_{cyl.}$ is the moment of inertia of the stationary parts in which the pistons and upper rod parts are supposed to be frozen in the mid-stroke position.

(3) Calculate the "coupling factor:"

$$K = \sqrt{\left(\frac{1-p}{p}\right)^2 \frac{I_{shaft}}{I_3} + 2\,\frac{1-p}{p}\,\frac{I_{shaft} I_{rec.}}{I_2 I_3}} \qquad \text{(c)}$$

in which the I_{shaft} is the combination of propeller and crank inertia defined already in Eq. (a), and in which $I_{rec.}$ is a fictitious moment of inertia found by placing half the reciprocating masses at the crank radius. For spur gears the second term under the square root is negative, whereas for planetary gears it is positive. It is noticed that for a direct drive, $p = 1$, the coupling K becomes zero.

(4) Pick the critical speeds off Figs. 1 and 2.

As an example, suppose that the "shaft critical" is 2000 r.p.m., the "frame" critical is 2500 r.p.m. for a stiff mount, and that the coupling factor $K = 0.30$, then Fig. 1 gives the speed 94 percent of 2000 = *1880 r.p.m.* and Fig. 2 gives 1.08 × 2500 r.p.m. = *2700 r.p.m.* It is seen that the shaft frequency is *diminished* from 2000 to 1880 by the gear effect.

On the other hand, for a flexible mount and a very strong coupling one might have:

$$\begin{aligned} (\text{r.p.m.})_{shaft} &= 2000 \\ (\text{r.p.m.})_{frame} &= 1000 \\ K &= 0.50 \end{aligned}$$

which, by the figures, gives the criticals *2290* and *872* and it is seen that the shaft critical is *raised* by the gear effect.

An inspection of the figures shows under which circumstances the gear effect is particularly large. In the first place, the shaft and gear critical speeds should be close to each other, so that one moves on the extreme curves of the family. In the second place, the coupling should be large, which means not only a large gear ratio, but more important, a small frame or cylinder inertia.

ANALYSIS

Fig. 3 shows a schematic view of the engine fitted with a spur-gear reduction. The problem is determined by the following six equations:

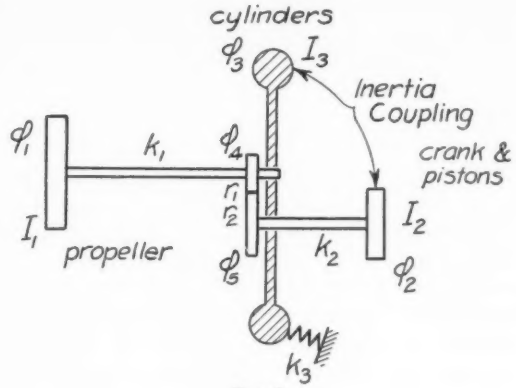
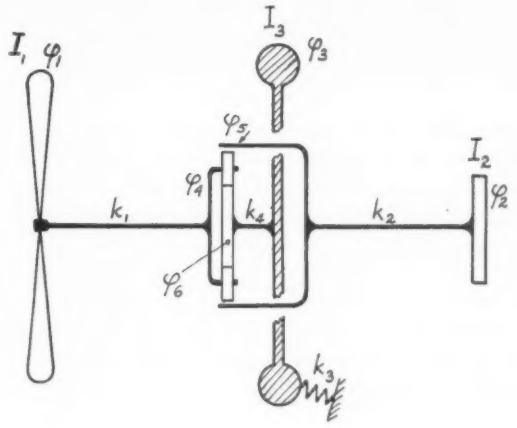


FIG. 3.



$$I_1\ddot{\varphi}_1 + k_1(\varphi_1 - \varphi_4) = 0 \tag{1}$$
$$I_2\ddot{\varphi}_2 + k_2(\varphi_2 - \varphi_5) - I_{rec.}\ddot{\varphi}_3 = 0 \tag{2}$$
$$I_3\ddot{\varphi}_3 + k_3\varphi_3 + T(r_1 + r_2) - I_{rec.}\ddot{\varphi}_2 = 0 \tag{3}$$
$$Tr_1 = k_1(\varphi_4 - \varphi_1) \tag{4}$$
$$Tr_2 = k_2(\varphi_5 - \varphi_2) \tag{5}$$
$$(\varphi_4 - \varphi_3)r_1 = (\varphi_3 - \varphi_5)r_2 \tag{6}$$

In all of these the angles φ are counted positive if clockwise seen from the right of Fig. 3. The last terms of the second and third equations express the "inertia coupling" between pistons and cylinders; the $I_{rec.}$ being the moment of inertia of half the reciprocating masses concentrated at the crank radius r:

$$I_{rec.} = r^2_{crank} \sum \frac{1}{2} m_{rec.} \cdot \tag{7}$$

The term $I_{rec.}\ddot{\varphi}_3$ expresses the clockwise torque exerted on the crank, if the crank is held still and the cylinders be given a clockwise acceleration $\ddot{\varphi}_3$. This causes the pistons to accelerate in and along the cylinders, giving forces in the connecting rods, which add up to form the torque indicated. Similarly the $I_{rec.}\ddot{\varphi}_2$ term in Eq. (3) is the clockwise torque exerted on the cylinders due to a clockwise acceleration $\ddot{\varphi}_2$ of the crank. These two terms express the "inertia coupling" between pistons and cylinders. This effect naturally exists in a non-geared engine as well, and thus there is some "coupling" between the two speeds of such an engine. However, it will follow later in the analysis that the *elastic* coupling brought about by the gears is a major influence, against which the *inertia* coupling appears as a small correction. Therefore, an extended analysis of this inertia coupling effect for non-geared engines has no practical significance.

The elastic gear coupling is expressed in Eq. (3) by the term containing the symbol T for the tooth pressure, which is positive if tending to turn both gears clockwise.

With these notations, Eqs. (1), (2), and (3) are the Newton equations for the three inertias; the fourth and fifth equations express *the assumption that the gears have no inertia*, so that the elastic torque from the shaft on each gear equals the counter torque due to tooth pressure. Finally Eq. (6) expresses a geometric relation regarding the gear rotations. The unknowns in this set are the five φ's and the pressure T.

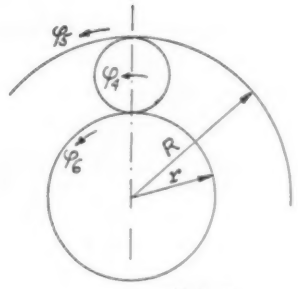


FIG. 4.

For an engine with *planetary* gears as illustrated in Fig. 4 the equations are very similar. Since the sun gear is assumed non-rigid, but rather attached to the frame through a flexibility k_4, there is one more equation than in the previous case:

$$I_1\ddot{\varphi}_1 + k_1(\varphi_1 - \varphi_4) = 0 \tag{8}$$
$$I_2\ddot{\varphi}_2 + k_2(\varphi_2 - \varphi_5) - I_{rec.}\ddot{\varphi}_3 = 0 \tag{9}$$
$$I_3\ddot{\varphi}_3 + k_3\varphi_3 + k_4(\varphi_3 - \varphi_6) - I_{rec.2}\ddot{\varphi} = 0 \tag{10}$$
$$Tr + k_4(\varphi_3 - \varphi_6) = 0$$
$$TR + k_2(\varphi_2 - \varphi_5) = 0$$
$$T(R + r) - k_1(\varphi_1 - \varphi_4) = 0$$
$$(\varphi_4 - \varphi_5)R + (\varphi_4 - \varphi_6)r = 0$$

The ratio of the propeller and engine speeds is $R/R + r$. The physical meaning of the various equations is very much the same as discussed with the expressions (1) to (6) for spur gears.

For the sake of generality the last four equations of the above set are rewritten in terms of the speed ratio $p = R/R + r$, while the tooth pressure T is eliminated, with the result:

$$k_4(\varphi_3 - \varphi_6) + (1 - p)k_1(\varphi_1 - \varphi_4) = 0 \quad (11)$$

$$k_2(\varphi_2 - \varphi_5) + pk_1(\varphi_1 - \varphi_4) = 0 \quad (12)$$

$$(\varphi_4 - \varphi_5) + \frac{1 - p}{p}(\varphi_4 - \varphi_6) = 0 \quad (13)$$

If in Eqs. (8) to (13) $k_4 = \infty$ is substituted, and consequently $\varphi_3 = \varphi_6$, they represent the special case of a rigidly supported sun gear. Eq. (11) then loses its meaning and has to be stricken out, reducing the set to 5 equations with the 5 unknowns φ_1 to φ_5.

On the other hand, if Eqs. (1) to (6) are rewritten in terms of a speed ratio $p = -r_2/r_1$ (negative because the propeller rotates in a direction opposite to the engine), and if the tooth pressure is eliminated from them, the result is identical with the set (8) to (13) for the rigid sun gear. Thus the kind of gearing has no influence on the problem; its entire characteristics are determined by the speed ratio p alone.

Proceeding to the solution of Eqs. (8) to (13), φ_4, φ_5, and φ_6 are eliminated and, as usual, $\ddot{\varphi}$ is replaced by $-\omega^2\varphi$, leading to:

$$\varphi_1[pI_1] + \varphi_2[I_2] + \varphi_3[-I_{rec.}] = 0$$

$$\varphi_1[(1 - p)I_1\omega^2] + \varphi_2[-I_{rec.}\omega^2] + \varphi_3[-k_3 + I_3\omega^2] = 0$$

$$\varphi_1\left[1 - \frac{I_1\omega^2}{k_1}\right] + \varphi_2\left[-p + p\frac{I_2\omega^2}{k_2} - (1 - p)\frac{I_{rec.}}{k_4}\omega^2\right] +$$

$$\varphi_3\left[-(1 - p)\left(1 + \frac{k_3}{k_4} - \frac{I_3\omega^2}{k_4}\right) - \frac{I_{rec.}\omega^2}{k_2}\right] = 0$$

and by solving the determinant of this system the frequency equation is found after some simplicfiation:

$$\left(\frac{\omega}{\omega_{sh}}\right)^4 - \left(\frac{\omega}{\omega_{sh}}\right)^2 \cdot \frac{1 + \frac{\omega_{fr}^2}{\omega_{sh}^2} + K^2 - \frac{I_{sh}I^2_{rec.}}{p^2I_1I_2I_3}}{1 - \frac{I_{2rec.}}{I^2I_3}} + \frac{\frac{\omega_{fr}^2}{\omega_{sh}^2}}{1 - \frac{I^2_{rec.}}{I_2I_3}} = 0 \quad (14)$$

in which the symbols ω_{sh}, ω_{fr} and K have been defined in Eqs. (a), (b), and (c). From this complicated quadratic equation in ω^2 two values for the frequency can be calculated. However, before proceeding with this, it is well to consider the order of magnitude of some of the terms. In the denominators the quantity $I_{rec.}^2/I_2I_3$ occurs, in which $I_{rec.}$ is the reciprocating mass at the crank radius, I_2 the reciprocating, rotating and crank pin masses at the same radius and I_3 the cylinder plus piston masses at a radius about equal to the connecting rod length. Thus I_2 is of the order of 4 times $I_{rec.}$, while I_3 is probably 100 or more times $I_{rec.}$, so that the combination $I^2_{rec.}/I_2I_3$ is of the order of one-fourth of one percent, which is negligible with respect to unity. For the same reason the term immediately after K^2 in Eq. (14) can be neglected with respect to K^2. With these simplifications the quadratic becomes:

$$\left(\frac{\omega}{\omega_{sh}}\right)^4 - \left(\frac{\omega}{\omega_{sh}}\right)^2 \cdot \left[1 + \frac{\omega_{fr}^2}{\omega_{sh}^2} + K^2\right] + \left(\frac{\omega_{fr}^2}{\omega_{sh}^2}\right) = 0$$

From the structure of this equation it is seen that for no coupling, *i.e.*, for $K = 0$, the roots are simply ω_{sh} and ω_{fr} as they should be. The appearance of the term K^2 makes the roots deviate from their uncoupled values.

The relative influence of the elastic gear coupling and the inertia coupling at the pistons also appears quite clearly from Eqs. (c) and (14). In the coupling factor (c) there are two terms of which the first one is wholly due to tooth pressure of the gears and the second is caused by a combination of the gears and the inertia effect. This second term is considerably smaller numerically than the first term for both types of gears, but whereas the second term subtracts from the first one for spur gears (p negative) it adds for planetary gears. However, since the first term is very much smaller for planetary gears than for spur gears, the total coupling K is greater for spur gears than for planetary systems.

In the case of a direct drive $p = 1$ and the coupling factor K disappears. From the above approximate frequency equation no change in the natural frequencies would seem to occur at all. However, Eq. (14) is the more accurate equation, and it is seen that the term following K^2 does remain with $p = 1$, and that term expresses the inertia coupling in a direct drive engine. It is very small and, if desired, its result on the critical speed can also be read directly off Figs. 1 and 2.

Turbulent Boundary Layer of an Aerofoil

K. FEDIAEVSKY, *Central Aero-Hydrodynamical Institute, Moscow*

(Received July 6, 1937)

1. Up to the present time in the solution of the problems concerning a turbulent boundary layer, velocity profiles were obtained theoretically or in a semi-empirical way either for the case of fluid moving in straight circular pipes, *i.e.*, for the case of a linear shearing stress distribution across the boundary layer (the power law, von Kármán logarithmic law), or for the case of flow with a constant stress distribution across the boundary layer (Prandtl-Nikuradse logarithmic law).

Evidently both these cases of shearing stress distribution across the boundary layer do not correspond to the conditions of an external flow around a curvilinear contour. Naturally such velocity profiles cannot represent the real conditions of the external flow around a curvilinear contour; for example they cannot represent the effect of the static pressure gradient.

Experiments show that in boundary layers with a positive or negative pressure gradient the velocity distribution differs greatly from that in a straight circular pipe. In the case of a positive static pressure gradient the real velocity profiles are less full and in the case of a negative static pressure gradient are more full than the velocity profile in a circular pipe. Figs. 1, 2, and 3 show the velocity distribution in boundary layers as obtained by Grushwitz.[5]

The curves are given in non-dimensional coordinates: the velocities are referred to the velocities on the external boundary of the boundary layer U_δ, and the distances from the wall y are referred to the boundary layer thickness δ. A velocity distribution curve is plotted according to the $^1/_7$ power law for comparison.

Consider the character of the shearing stress distribution for a boundary layer with a pressure gradient assuming that the velocity profile depends on the character of shearing stress distribution across the boundary layer.

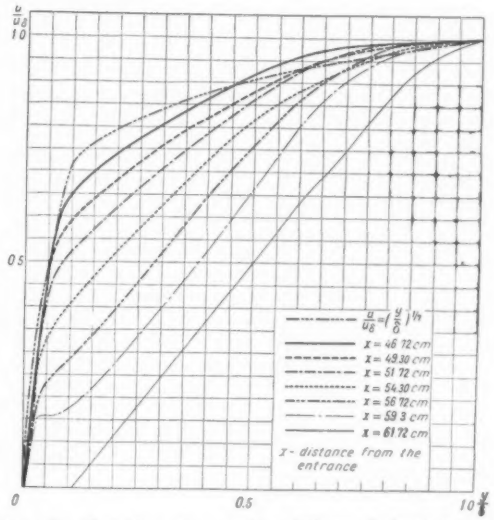


FIG. 2. Boundary layer of a diffuser derived from profile 3.

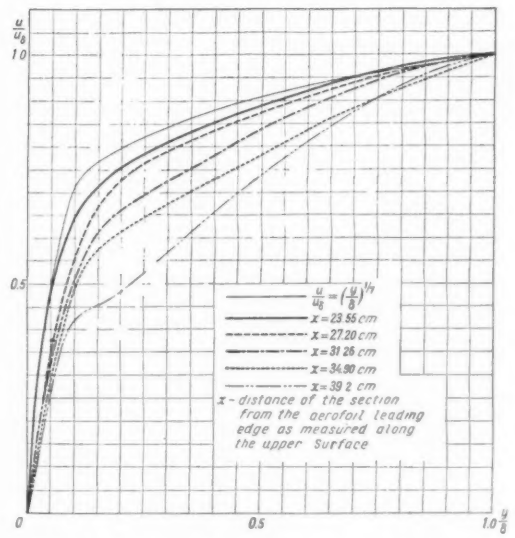


FIG. 1. Göttingen 397; $\alpha = 6°$, chord $t = 40$ cm.

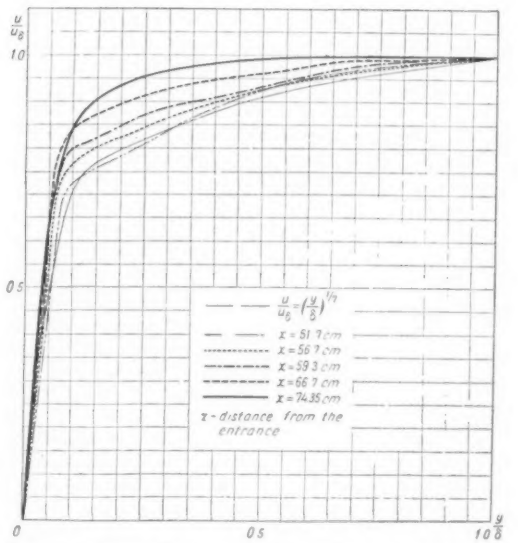


FIG. 3. Boundary layer of a confuser derived from profile 5.

2. Express the shearing stress in a turbulent boundary layer as referred to the shearing stress at the wall in the form of a polynomial

$$\frac{\tau}{\tau_0}=A_0+A_1\left(\frac{y}{\delta}\right)+A_2\left(\frac{y}{\delta}\right)^2+A_3\left(\frac{y}{\delta}\right)^3+A_4\left(\frac{y}{\delta}\right)^4+\ldots\ldots \quad (1)$$

the coefficients of which may be determined from conditions corresponding to the ratio τ/τ_0 and its derivatives at the wall and at the external boundary of the boundary layer. For a polynomial of the fourth power there are plenty of such conditions.

Give the Prandtl differential equation of motion in a plane boundary layer in the form

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{1}{\rho}\frac{\partial \tau}{\partial y} \quad (2)$$

where u and v are the velocity components along the x and y axes. These are the components of real velocity in the case of laminar motion and the components of mean velocity in the case of turbulent motion:

ρ = the mass density of the fluid
p = pressure, the real in the case of laminar motion and the mean in the case of turbulent motion
τ = the friction stress for laminar motion.

$$\tau=\mu\frac{\partial u}{\partial y}$$

where μ is the dynamic viscosity of the fluid. For turbulent motion

$$\tau=\mu\frac{\partial u}{\partial y}-\rho\overline{u'v'}$$

where $\overline{u'v'}$ is the mean product of fluctuation velocities. For turbulent motion the term

$$\frac{\partial(\rho\overline{u'^2})}{\partial x}$$

of Eq. (2) being negligibly small is omitted.

I. For $y = 0$ (*i.e.*, at the wall)

$$\frac{\tau}{\tau_0}=1 \quad (I)$$

II. For $y = 0$ (*i.e.*, at the wall) the left side of Eq. (2) vanishes and

$$\frac{\partial \tau}{\partial y}=\frac{\partial p}{\partial x}$$

therefore

$$\frac{\partial\left(\frac{\tau}{\tau_0}\right)}{\partial\left(\frac{y}{\delta}\right)}=\frac{\delta}{\tau_0}\frac{\partial p}{\partial x} \quad (II)$$

III. At the external boundary of a boundary layer, *i.e.*, for $y = \delta$

$$\frac{\tau}{\tau_0}=0 \quad (III)$$

which follows from the definition of the boundary layer.

IV. Differentiating Eq. (2) with respect to y:

$$\frac{\partial u}{\partial y}\frac{\partial u}{\partial x}+u\frac{\partial^2 u}{\partial x\partial y}+\frac{\partial v}{\partial y}\frac{\partial u}{\partial y}+v\frac{\partial^2 u}{\partial y^2}=-\frac{1}{\rho}\frac{\partial^2 \tau}{\partial y^2} \quad (3)$$

as due to the Prandtl second differential equation the pressure is constant across the boundary layer. At the wall (*i.e.*, for $y = 0$) the left side of Eq. (3) vanishes as $\partial u/\partial x = -\partial v/\partial y$ (due to the continuity equation) and

$$\frac{\partial^2 \tau}{\partial y^2}=0$$

therefore

$$\frac{\partial^2\left(\frac{\tau}{\tau_0}\right)}{\partial\left(\frac{y}{\delta}\right)^2}=0 \quad (IV)$$

V. At last it may be assumed that the first derivative of friction stress vanishes at the external boundary of a turbulent boundary layer similar to the Polhausen condition of the first derivative being equal to zero at the external boundary of a laminar boundary layer, and therefore at $y = \delta$

$$\frac{\partial\left(\frac{\tau}{\tau_0}\right)}{\partial\left(\frac{y}{\delta}\right)}=0 \quad (V)$$

So far as is known the idea of presenting the shearing stresses in the boundary layer in the form of a polynomial was first suggested by Buri in 1931, but Buri[1] proposed to express the shearing stresses as referred to the shearing stresses at the wall in the form of the polynomial

$$\frac{\tau}{\tau_0}=1+\Gamma_a\left(\frac{y}{\Theta}\right)+\Gamma_b\left(\frac{y}{\Theta}\right)^2+\ldots.$$

where Θ is the so-called "length of the impulse loss," *i.e.*, a linear value proportional to the impulse loss in the boundary layer. This value is determined from the formula

$$\Theta=\int_0^\delta\frac{U}{U_\delta}\left(1-\frac{U}{U_\delta}\right)dy=\frac{1}{U_\delta^2}\int_0^\delta(UU_\delta-U^2)dy$$

It can be seen that Θ is a value proportional to the difference between the momentum of the mass of fluid moving in the boundary layer with a speed equal to that at the external boundary and the actual momen-

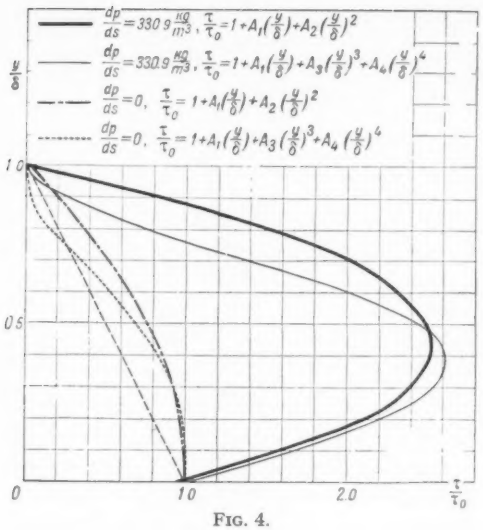

dp/ds = 330.9 kG/m³, τ/τ₀ = 1 + A₁(y/δ) + A₂(y/δ)²
dp/ds = 330.9 kG/m³, τ/τ₀ = 1 + A₁(y/δ) + A₃(y/δ)³ + A₄(y/δ)⁴
dp/ds = 0, τ/τ₀ = 1 + A₁(y/δ) + A₂(y/δ)²
dp/ds = 0, τ/τ₀ = 1 + A₁(y/δ) + A₃(y/δ)³ + A₄(y/δ)⁴
y/δ
1.0
0.5
0
1.0
2.0
τ/τ₀

FIG. 4.

tum of the boundary layer. However, the polynomial coefficients suggested by Buri cannot be determined so far as the values of the shearing stresses and their derivatives may be found from the conditions at the wall only, *i.e.*, for $y/\Theta = 0$. But even from these Buri has used conditions I and II only.

Thus the expression suggested by Buri does not represent the shearing stress profile across the boundary layer and therefore cannot be used in the further analysis.

Determine the coefficients of polynomial (1) according to the conditions obtained in the analysis.

(a) For conditions I, II, III, IV, and V.

$$\left.\begin{aligned} A_0 = 1;\quad A_1 = \frac{\delta}{\tau_0}\frac{\partial p}{\partial s};\quad A_2 = 0;\\ A_3 = -4 - 3\frac{\delta}{\tau_0}\frac{\partial p}{\partial s};\quad A_4 = 3 + 2\frac{\delta}{\tau_0}\frac{\partial p}{\partial s}\end{aligned}\right\} \quad (4)$$

(b) For conditions I, II, III, and IV:

$$\left.\begin{aligned} A_0 = 1;\quad A_1 = \frac{\delta}{\tau_0}\frac{\partial p}{\partial s};\\ A_2 = -3 - 2\frac{\delta}{\tau_0}\frac{\partial p}{\partial s};\quad A_3 = 2 + \frac{\delta}{\tau_0}\frac{\partial p}{\partial s}\end{aligned}\right\} \quad (5)$$

(c) And for conditions I, II, and III:

$$A_0 = 1;\quad A_1 = \frac{\delta}{\tau_0}\frac{\partial p}{\partial s};\quad A_2 = -1 - \frac{\delta}{\tau_0}\frac{\partial p}{\partial s} \quad (6)$$

It should be noted first that conditions I, II, III, IV, and V are equally applicable both for a laminar and a turbulent boundary layer; thus in the range of interpolation accuracy of the actual shearing stress distribution by the polynomial (1), the non-dimensional shearing stresses profiles in a laminar and in a turbulent boundary layer may be considered equal at equal value of $(\delta/\tau_0)(\partial p/\partial s)$, *i.e.*, at equal relationship between the pressure force $\delta\partial p/\partial s$ and the shearing

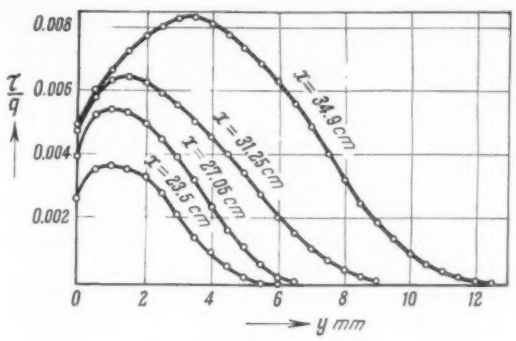


FIG. 5.

force at the wall τ_0, acting on the boundary layer elements.

Unfortunately it is not yet possible to evaluate theoretically the degree of approximation of the polynomial interpolation used, therefore the choice of a combination of conditions may be made on the basis of best agreement of the theoretical values of shearing stresses and velocities with the same experimental data.

The nature of the shearing stress profile at a positive pressure gradient was confirmed by results obtained by Gruschwitz. Fig. 5 shows the shearing stress profile of four boundary layer sections of a wing at an angle of incidence of $\alpha = 12°$ as obtained by Gruschwitz. The absolute values of shearing stresses as obtained by Gruschwitz slightly differ from corresponding theoretical data. It is supposed that this difference may be attributed chiefly to the inaccuracy of the experimental determination of the friction intensity (referred to by Gruschwitz himself). The matter is that the experimental determination of the friction intensity requires a graphical differentiation of the total energy of the fluid along the streamlines. In view of the small number of sections where the total energy was measured such a differentiation could hardly be made with sufficient accuracy and the results may be to a great extent arbitrary.

The choice, therefore, of a combination of conditions for a polynomial expressing the shearing stresses may be made at present on the basis of the best agreement of velocity values as obtained theoretically with corresponding experimental data, so far as the experimental determination of the boundary layer velocities gives much more accurate results than the experimental determination of the shearing stresses.

Fig. 4 shows the non-dimensional shearing stress profiles for the cases of $\partial p/\partial s > 0$ and $\partial p/\partial s = 0$. In this diagram the stress profiles are plotted for the combination of conditions I, II, and III and also for the combination of conditions I, II, III, IV, and V. It may be seen that the combination even of the three conditions I, II, and III determines the general nature of the shearing-stress profile.

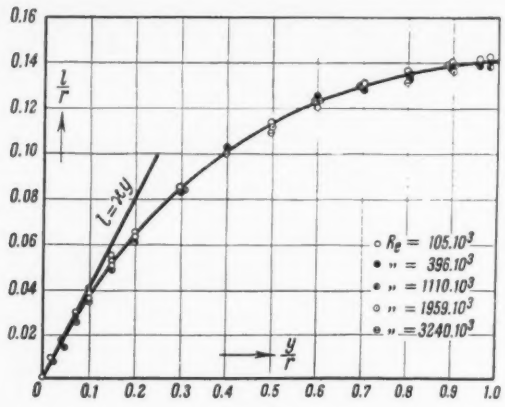


FIG. 6.

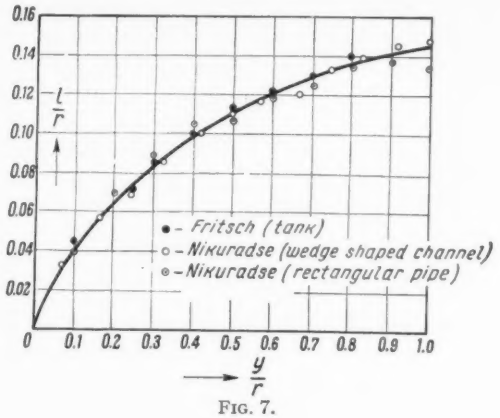


FIG. 7.

It is of interest to note that the shearing stress profile for the case of a flat plate, *i.e.*, at $\partial p/\partial s = 0$, shows not so great a difference from the linear shearing stress profile corresponding to the case of a straight circular pipe, as the shearing stress profile at $\partial p/\partial s > 0$. It therefore becomes evident that the use of velocity profiles as obtained for a straight circular pipe gives comparatively comprehensive results if $\partial p/\partial s$ is close to or equal to zero (the cases of a flat plate, or an airship hull).

3. In order to state the law of variation of velocity across the boundary layer it is necessary to accept a dependence between the shearing stress and the velocity. In the case of a turbulent boundary layer, it means the assumption of a given model of turbulence.

Express the shearing stress by means of the Prandtl law of mixing line (Mischungsweg):

$$\tau = \rho l^2 \left(\frac{du}{dy}\right)^2 \qquad (7)$$

where l is the so-called "Mixing line" ("Mischungsweg") that denotes a value analogous to a free mean path of molecules in the kinetic theory of gases. The mixing line in a turbulent flow represents a value proportional to the motion of molar volume of fluid across the direction of the basic flow.

There are different points of view concerning the parameters of the mixing line function. Kármán states that the mixing line is determined by the ratio of the first velocity derivative with respect to y to the second derivative, *i.e.*, the turbulence is determined locally. According to Prandtl in the case when the shearing stress across the boundary layer is constant the mixing line is determined by the distance from the wall and, as a first approximation, he proposes to consider the mixing line simply proportional to this distance.

Such a great difference in concepts concerning the mixing line nature makes one consider the available experimental data.

The non-dimensional mixing line, *i.e.*, the mixing line referred to the pipe radius r is only the function of the non-dimensional distance y/r from the wall and is independent of the Reynolds Numbers according to the well-known experimental work by Nikuradse. This is valid in the case of smooth circular pipes at Reynolds Numbers above 100,000. Fig. 6 shows the dependence of the non-dimensional mixing line upon the non-dimensional distance from the wall at different Reynolds Numbers as obtained by Nikuradse. In this case the Reynolds Numbers were calculated on the basis of pipe diameters and of mean velocities. The dependence shown on Fig. 6 may be easily expressed by the following interpolation formula developed by Prandtl:

$$\frac{l}{r} = 0.14 - 0.08\left(1 - \frac{y}{r}\right)^2 - 0.06\left(1 - \frac{y}{r}\right)^4 \qquad (8)$$

It was found that such a distribution of the non-dimensional mixing line takes place not only in circular pipes but also in channels with parallel walls. That is confirmed by experimental data obtained by Nikuradse and Fritsch[7] as shown on Fig. 7. In this case the value r represents the half width of the channel. Besides, the same distribution of non-dimensional mixing lines takes place also in rough circular pipes (see reference 9, Fig. 19).

The analysis of data obtained by Doench and Nikuradse[3,4] shows in the case of a flat diffuser approximately the same distribution of the non-dimensional mixing lines as in the above-mentioned cases, and, what is of greatest importance, almost the same value of the non-dimensional mixing line on the axis (on the external boundary of the boundary layer). Figs. 8 and 9 show the distribution of the non-dimensional mixing lines in flat diffusers as obtained by Doench (Fig. 8) and Nikuradse (Fig. 9) for different angles of divergence. For flat confusers the distribution of the non-dimensional mixing lines (Mischungsweg) is of a different type.

Strictly speaking the curves on Fig. 9 for a flat diffuser show also some dependence of the non-dimen-

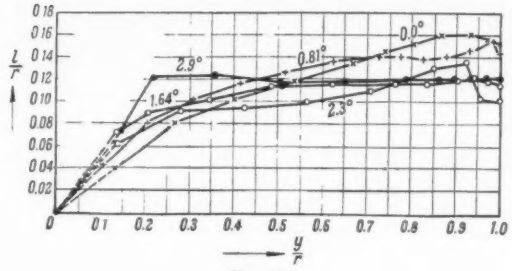


FIG. 8.

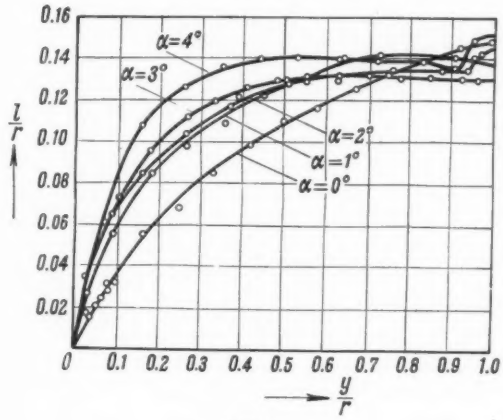


FIG. 9.

sional mixing line upon the divergence angle of the diffuser and, therefore, upon the pressure gradient.

However, taking into account that at an angle of divergence of $\alpha = 0$ the pressure gradient is already negative, it may be stated that the pressure gradient effect on the distribution of the non-dimensional mixing line at positive or at small negative pressure gradients is comparatively small and in any case smaller than the same effect on the velocity profile.

Thus the non-dimensional mixing line may be considered as a more general value as compared with the velocity profile and approximated as identical for a more general class of boundary layers.

On the other hand it should be admitted that the static pressure gradient effect on the shearing stress profile is extremely great. In fact, as shown on Fig. 4, the shearing stress profile at $\partial p/\partial s > 0$ for the upper surface of the aerofoil at an incidence of $\alpha = 12°$ is quite different from that at $\partial p/\partial s = 0$ in the case of the same shearing stress at the wall.

On the basis of the above, the non-dimensional mixing line is supposed to be dependent only on the non-dimensional distance from the wall and the difference in the velocity profiles due to the difference in the frictional stresses. This is a further approximation of the developed method as compared with the transfer of the velocity profile from the internal into the external problem used in preceding work.

Making this suggestion the explanation of the smaller fullness of the velocity profiles in the case of a positive

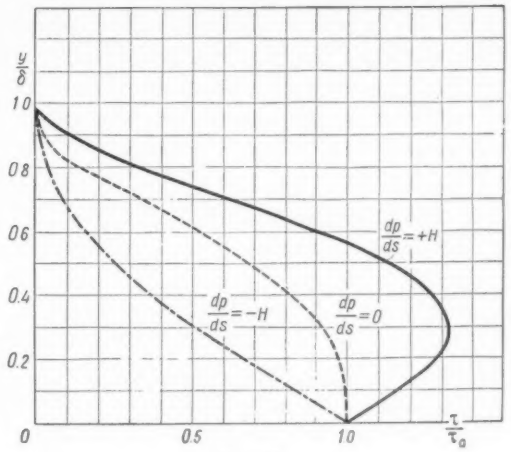


FIG. 10a.

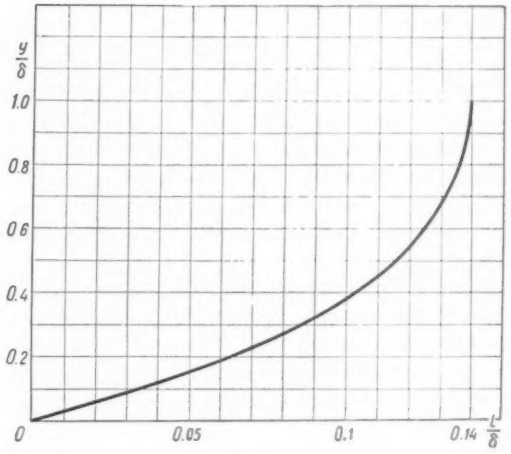


FIG. 10b.

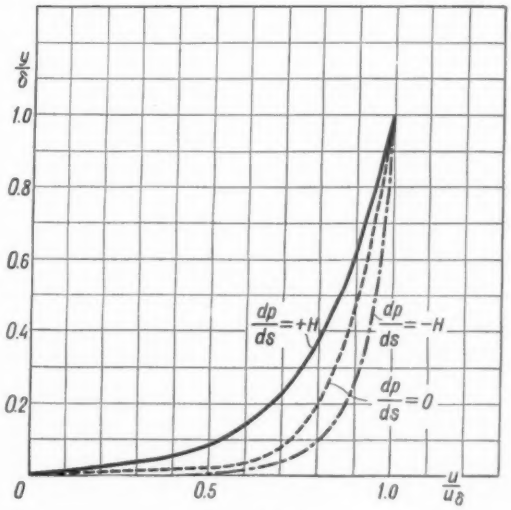


FIG. 10c.

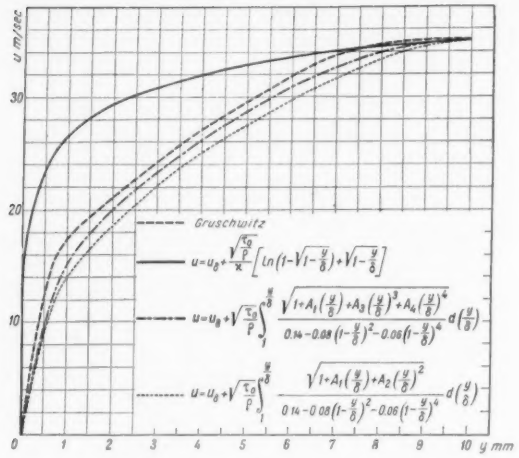


FIG. 11. Göttingen 397 aerofoil. $t = 40$ cm.; $\alpha = 12°$; $x = 31.24$ cm.; $\delta = 0.009975$ m.; $\tau_2 = 0.3405$ kg./m.²; $dp/ds = 254$ kg./m.³

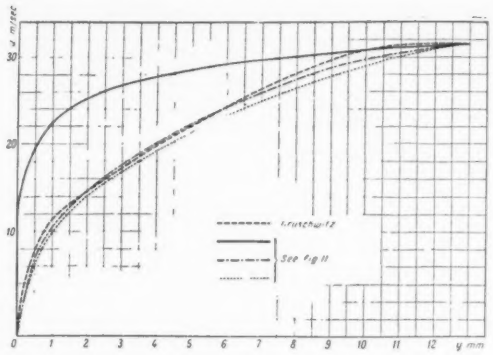


FIG. 12. Göttingen 397 aerofoil. $t = 40$ cm.; $\alpha = 12°$; $x = 34.9$ cm.; $\delta = 0.013$ m.; $\tau_2 = 0.314$ kg./m.²; $dp/ds = 187$ kg./m.³

pressure gradient and of its greater fullness in the case of a negative pressure gradient is immediately obtained. In fact, according to Eq. (7), at an equal distribution of the non-dimensional mixing line the velocity derivative with respect to y will increase with the increase of the shearing stress τ. In its turn the shearing stress τ at equal non-dimensional distances from the wall and at equal values of τ_0 will increase with the increase of the pressure gradient (see Fig. 10).

Thus it follows that at positive pressure gradient the velocity profile will have a less full form than at $\partial p/\partial s = 0$ and, *vice versa*, at negative pressure gradients the velocity profile will be more thick than at $\partial p/\partial s = 0$.

The law of the velocity distribution across a boundary layer may be easily found by using the Prandtl formula for a non-dimensional mixing line distribution in case of the external boundary layer. Thus this formula may be written as follows:

$$\frac{l}{\delta} = 0.14 - 0.08\left(1 - \frac{y}{\delta}\right)^2 - 0.06\left(1 - \frac{y}{\delta}\right)^4 \ldots . (8)$$

4. On the basis of Eq. (7), the following differential equation may be obtained:

$$du = \sqrt{\frac{\tau}{\rho}}\frac{1}{l}\,dy = \sqrt{\frac{\tau}{\rho}}\frac{1}{\left(\frac{l}{\delta}\right)}\,d\left(\frac{y}{\delta}\right) \qquad (9)$$

an integration of which from 1 to y/δ gives

$$U = U\delta + \int_1^{y/\delta} \sqrt{\frac{\tau}{\rho}}\frac{1}{\left(\frac{l}{\delta}\right)}\,d\left(\frac{y}{\delta}\right) \qquad (10)$$

Substituting the values of τ and l/δ from Eqs. (1) and (8) in Eq. (10):

$$U = U_\delta + \sqrt{\frac{\tau_0}{\rho}}\int \frac{\sqrt{1 + A_1\left(\frac{y}{\delta}\right) + A_2\left(\frac{y}{\delta}\right)^2 + \ldots .}}{0.14 - 0.08\left(1 - \frac{y}{\delta}\right)^2 - 0.06\left(1 - \frac{y}{\delta}\right)^4}\,d\left(\frac{y}{\delta}\right) \qquad (11)$$

is obtained, since $A_0 = 1$ at all times.

It is shown that the integral of the right part of Eq. (11) will reduce to an elliptical integral of the second kind when the combination of conditions I, II, III, IV, and V or the combination of conditions I, II, III, and IV are used for τ. In particular, for the combination of conditions I, II, III, IV, and V, Eq. (11) will assume the following form:

$$U = U_\delta + \sqrt{\frac{\tau_0}{\rho}}\int_1^{y/\delta} \frac{\sqrt{1 + A_1\left(\frac{y}{\delta}\right) + A_3\left(\frac{y}{\delta}\right)^3 + A_4\left(\frac{y}{\delta}\right)^4}}{0.14 - 0.08\left(1 - \frac{y}{\delta}\right)^2 - 0.06\left(1 - \frac{y}{\delta}\right)^4}\,d\left(\frac{y}{\delta}\right) \qquad (12)$$

For the combination of conditions I, II, and III the integral of the right part of Eq. (11) may be taken in its finite form. In this case Eq. (11) assumes the following form:

$$U = U_\delta + \sqrt{\frac{\tau_0}{\rho}}\int_1^{y/\delta} \frac{\sqrt{1 + A_1\left(\frac{y}{\delta}\right) + A_2\left(\frac{y}{\delta}\right)^2}}{0.14 - 0.08\left(1 - \frac{y}{\delta}\right)^2 - 0.06\left(1 - \frac{y}{\delta}\right)^4}\left(\frac{y}{\delta}\right) \qquad (13)$$

Figs. 11 and 12 show the velocity profiles for two sections of the boundary layer of the upper surface of an aerofoil as obtained by Gruschwitz at an angle of incidence of $\alpha = 12°$. These two sections are the nearest to the critical point of flow separation. Therefore the velocity profiles in these sections are of a

special interest. The velocity profiles for these sections as plotted according to Eqs. (12) and (13) show a sufficiently good agreement with the experimental data. For comparison, on the same diagram are given the velocity profiles as plotted according to Kármán's formula for straight circular pipes.

$$U = U_\delta + \frac{\sqrt{\frac{\tau_0}{\rho}}}{\kappa}\left[ln\left(1 - \sqrt{1 - \frac{y}{\delta}}\right) + \sqrt{1 - \frac{y}{\delta}}\right] \quad (14)$$

where κ is a constant approximately equal to 0.4.

The curves calculated according to Eqs. (12) and (13) and that of Kármán are conditionally plotted on Figs. 11 and 12 at the origin.

The velocity profiles plotted according to Eq. (12) show a better agreement with the experiment than the profiles plotted according to Eq. (13); this may be attributed to a greater degree of approximation for the shearing stress value in Eq. (12) as compared with Eq. (13).

The combination of conditions I, II, III, and IV or I, II, III, and V gives a worse agreement between theoretical and experimental profiles than in the case of conditions I, II, III, IV, and V or even the combination of I, II, and III.

The construction of velocity profiles for a turbulent boundary layer which gives a sufficiently good agreement with the experiment allows the attacking of the problem of a turbulent boundary layer separation. Besides, it allows a more accurate determination of the drag of protuberances and roughnesses inside the boundary layer.

5. Similarly to the Prandtl "dynamical speed of friction"

$$V_* = \sqrt{\frac{\tau_0}{\rho}} \quad (15)$$

a value corresponding to the pressure force, acting on the boundary layer section, can be introduced denoting it as p_*. Then

$$p_* = \sqrt{\frac{\delta}{\rho}\frac{\partial p}{\partial s}} \quad (16)$$

This value could be called the "dynamical speed of pressure."

Introducing the above value, Eq. (13), in which the integral is taken in its finite form, may be expressed as follows:

$$U = U_\delta + 14.3\,\frac{(2V_*^2 + p_*^2)^2}{(V_*^2 + p_*^2)^{3/2}}\left[L_1 ln \frac{\left(\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}}\right)^{1/2} - \left(\frac{V_*^2}{V_*^2 + p_*^2}\right)^{1/2}}{\left(\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}}\right)^{1/2} + \left(\frac{V_*^2}{V_*^2 + p_*^2}\right)^{1/2}} + \right.$$

$$\frac{M_2}{2} ln \frac{\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}} - 2E\left(\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}}\right)^{1/2} + D}{\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}} + 2E\left(\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}}\right)^{1/2} + D} + \quad (17)$$

$$\left. G\,\mathrm{arctg}\,\frac{F\left(\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}}\right)^{1/2}}{D - \left(\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}}\right)} + H\,\mathrm{arctg}\,P\left(\frac{\frac{V_*^2}{V_*^2 + p_*^2} + \frac{y}{\delta}}{1 - \frac{y}{\delta}}\right)^{1/2}\right]_1^{y/\delta}$$

where the coefficients L_1, M_2, D, E, F, G, H, P are non-dimensional values depending on V_*^2 and p_*^2 only. However, since the presence of a laminar sub-layer was not accounted for in Eq. (13), the latter, as well as the Kármán formula

$$U = U_\delta + \frac{V_*}{\kappa}\left[ln\left(1 - \sqrt{1 - \frac{y}{\delta}}\right) + \sqrt{1 - \frac{y}{\delta}}\right] \tag{14}$$

and the Prandtl-Nikuradse formula

$$U = U_\delta + \frac{V_*}{\kappa} ln \frac{y}{\delta} \tag{18}$$

does not satisfy the conditions at the wall, as for y/δ one has $U = -\infty$.

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Pressure Distribution on a Wing with Circular Plan Form

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January 27, 1937

Introduction

FOR large aspect ratio wings, the aerodynamical force coefficients found by experiment agree closely with the values calculated by using the wing theory of finite span and by introducing a correction factor for the reduction of the circulation about the wing due to viscosity. The usual wing theory of finite span is limited in its application to wings of aspect ratio greater than three. For aspect ratios smaller than this value, the experimental results no longer agree with the results calculated by using the wing theory of finite span, since the type of airflow over the wing of small aspect ratio differs considerably from that over the wing of large aspect ratio.

Experimental investigations of small aspect ratio wings have been conducted by Flügel, Zimmerman, and Winter, and a theory for wings of very small aspect ratio has recently been developed by Dr. William Bollay; however, experimental information regarding the pressure distribution is lacking.

The pressure distribution on a wing with circular plan form eight inches in diameter was investigated at a Reynolds Number of approximately 410,000 based on the root chord.

The wing was constructed of brass with a Clark Y airfoil section and no dihedral. A number of channels running from the root chord to the wing tip were milled on both the upper and lower surfaces of the wing. Brass tubes one-eighth in. diameter were inlaid in the channels and soldered rigidly to the wing. A number of static orifices of one-thirty-second in. diameter were drilled into the tubes. The tubes were inlaid in the wing in such a manner that they were collected at the lower surface of the root chord near its trailing edge where they were led through a streamline strut and connected by means of rubber tubes to a verticle multiple manometer which was located in the working chamber of the tunnel. A pitot placed in the working section of the tunnel was also connected to the multiple manometer for measurement of dynamic pressure.

Ozalid paper was placed behind the multiple manometer columns, and exposures were made by flashing a 1000 watt lamp for a period of 25 seconds, the lamp being located one foot in front of the manometer board. The data obtained from the shadowgraph picture were, therefore, the average values of the pressure during the exposure period.

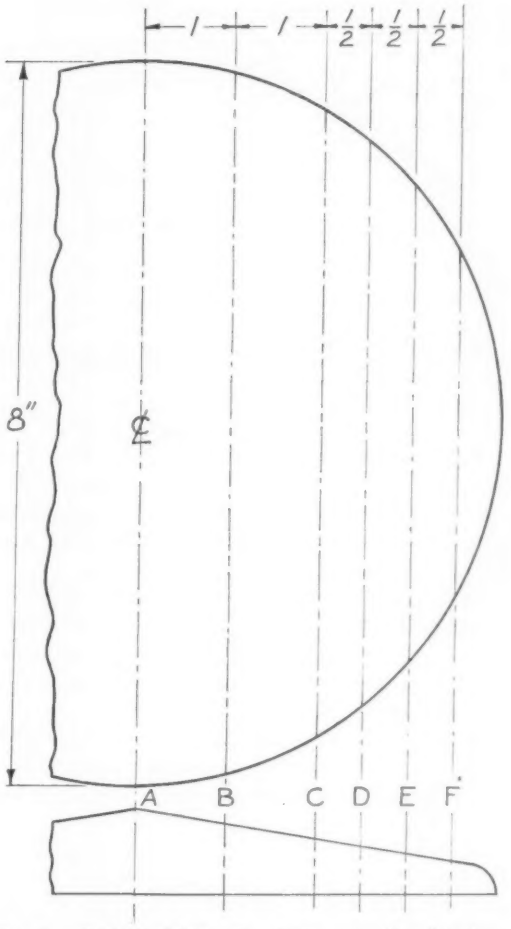

FIG. 1. Clark Y airfoil. Plan form and orifice location.

Strips of thin cellophane tape were used to seal all static orifices except those at a particular chord station whose pressure distribution was desired.

The wind tunnel used was an Eiffel type with an actual working section of 15 in. diameter, the working section being surrounded by an air-tight chamber. A four-bladed metal propeller of 22 in. diameter, directly driven by a 15 hp. induction motor, was mounted in the tunnel. The maximum wind velocity obtainable was about 91 m.p.h. The velocity survey in the working section of the tunnel showed uniform velocity distribution up to about 1.5 in. from the working section boundary.

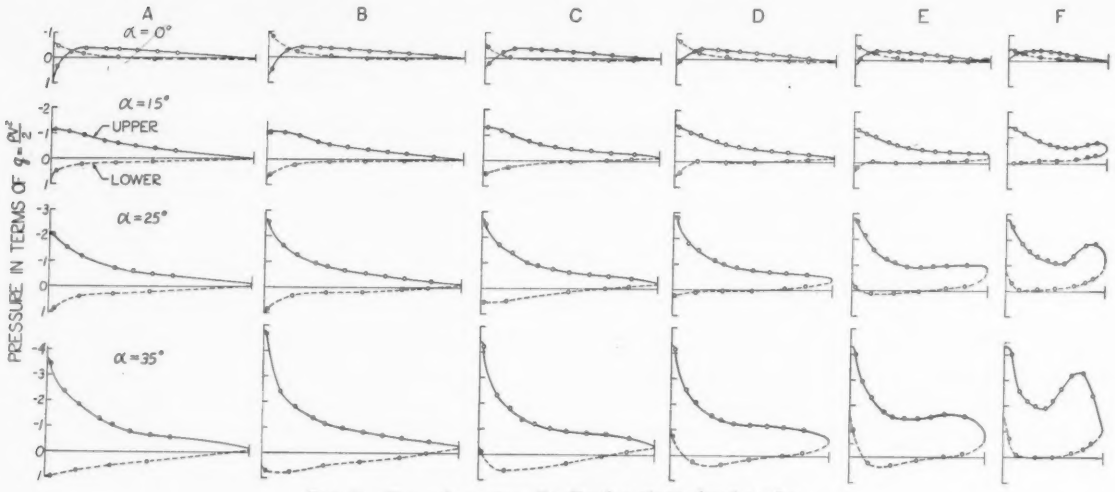

FIG. 2. Normal pressure distribution along chord station.

PRESSURE DISTRIBUTION

The pressure distribution test was made by taking three shadowgraph pictures for each chord station at various angles of attack from zero to near the stall at 5° intervals. Fig. 1 shows the locations of the static orifices on the wing. The static pressure readings were calculated in terms of the dynamic pressure, and the mean values were plotted along each chord station. Fig. 2 presents the results of some of the normal pressure measurements at various chord stations.

The values of the normal force coefficient C_N' were determined from the normal pressure diagrams as follows: $C_N' = A/qc$, where A is the integrated area of the pressure diagram, c = section chord, and q = dynamic pressure.

The locations of longitudinal centers of pressure were determined from the pressure diagrams by calculating the points of the resultant normal pressure line intersection with the chord line.

The values of C_N' at the chord station at each angle of attack were plotted along the semi-span, and the value of the average normal force coefficient, C_N, along the semi-span was determined by $C_N = A/(b/2)$, where A is the integrated area of the C_N diagram plotted along the semi-span, and b = span.

The approximate lift coefficient, C_L, at each angle of attack was determined by multiplying cos α by the corresponding C_N.

The α used in plotting is the geometrical angle of attack as measured from the lower surface of the wing, no corrections being made for the induced angle.

RESULTS AND DISCUSSION

The results of the pressure diagrams in Fig. 2 show that the magnitude of negative pressures over the upper surface of the wing near the trailing edge of the wing tip is greatly increased by an increase of angle of attack

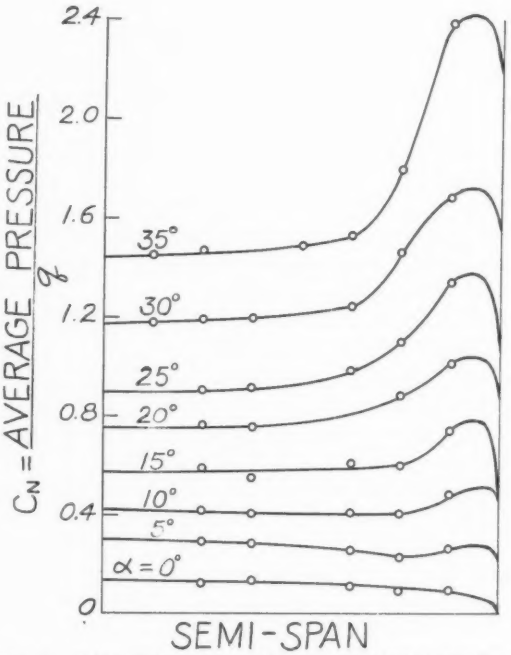

FIG. 3. Distribution of normal force coefficient along the semi-span.

and that the stalling angle is greatly delayed. The high suction over the upper surface near the trailing edge of the wing tip is a local phenomenon and does not extend toward the root chord of the wing. This suction always occurs with a finite wing because of the presence of tip vortices, although the magnitude of the suction varies with the shape and plan form of wing tip. Near the wing tip the pressure on the lower surface of the wing is reduced at large angle of attack because the velocity of airflow from the region below the wing and around the wing tip toward the negative pressure region over the upper surface of the wing, increases in order to equalize the pressure difference.

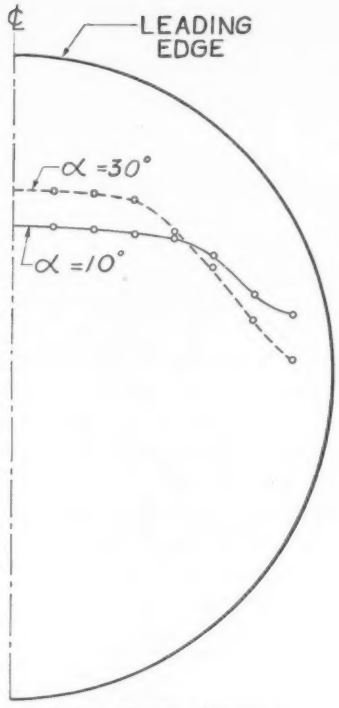

FIG. 4. Center of pressure.

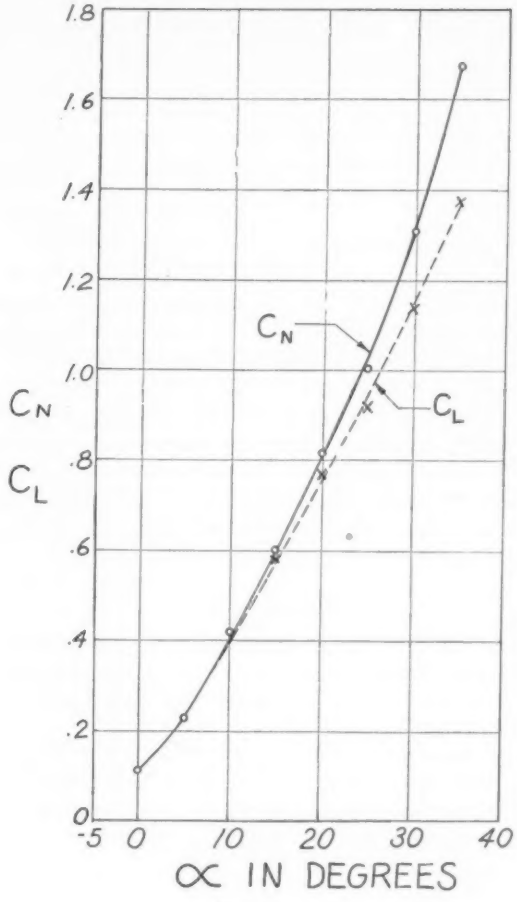

FIG. 5.

The distribution of the normal force coefficient along the semi-span is presented in Fig. 3. The increase of normal force coefficient with increase of angle of attack is fairly uniform from the root chord to about half way toward the wing tip; however, near the wing tip the rate of increase of the normal force coefficient is greater.

Fig. 4 gives the position of the longitudinal centers of pressure along the semi-span at the angles of attack of 10° and 30°. As the angle of attack increases, the position of the center of pressure moves forward for the section of the wing from the root chord to about half way toward the wing tip, while near the wing tip it moves rearward because of an increase in magnitude of suction over the upper surface near the trailing edge of the wing tip.

Fig. 5 gives the normal force coefficients and the approximately calculated lift coefficients plotted against the angles of attack. The slope of the lift curve increases with increase in the angle of attack because the local lift coefficient near the wing tip increases rapidly with the angle of attack.

The local stall of the wing occurs first at the wing tip and travels in toward the root chord. Table 1 gives the observed local stalling angle.

TABLE 1

Section Chord	Stalling Angle in Degrees and Minutes
A (root chord)	40°
B	40° 25 min.
C	40° 25 min.
D	38° 5 min.
E	38° 5 min.
F	36° 45 min.

CONCLUSIONS

(1) The magnitude of negative pressure over the upper surface of the wing near the trailing edge of the wing tip increases with an increase of angle of attack.

(2) Stalling angle is increased due to the short gap between the two wing tip vortices.

(3) At a very low angle of attack the pressure distribution over the wing of small aspect ratio is very similar to that of a wing of large aspect ratio.

(4) Maximum lift coefficient for the airfoil with circular plan form is greater than that of a conventional wing.

An Alignment Chart for the Allowable Stresses for Spruce Beams in Bending and Compression

RUSSELL M. CARLSON, *University of Minnesota*

(Received May 28, 1937)

Summary

A NOMOGRAM for the determination of the allowable stresses in wood beams under bending and compression is given in Aeronautics Bulletin No. 26, Fig. 18. This chart is complicated and somewhat difficult to use, especially for one unfamiliar with its operation. Problems may be solved more simply with the use of the accompanying alignment chart, Fig. 1, developed by the author. It is believed that this new chart will give a quicker and more accurate solution than the nomogram referred to above.

Development

The equation for the allowable stress was developed from an explanation of the curves of the nomogram in Niles and Newell "Airplane Structures" and from the nomogram itself. The equation involves complicated functions which are discontinuous and therefore are difficult to write as algebraic expressions. In terms of functions, however, the equation may be expressed by:

$$\frac{9400\,\psi_1(b'/b,\, t_c/h) - \psi_2(L/\rho,\, b'/b,\, t_c/h)}{1 - \psi_3(L/\rho,\, b'/b,\, t_c/h)} = \frac{9400\,\psi_1(b'/b,\, t_c/h) - A}{1 - f_b/f_t}$$

where b' = web thickness
b = beam width
t_c = compression flange thickness
h = total height of beam
L/ρ = slenderness ratio
A = allowable stress
f_b = imposed bending stress
f_t = total imposed stress

This equation was used to give an alignment chart solution involving: (1) Two parallel straight lines and a diagonal; (2) two parallel straight lines and a curved net; and (3) a combination of parts (1) and (2) to give the complete solution.

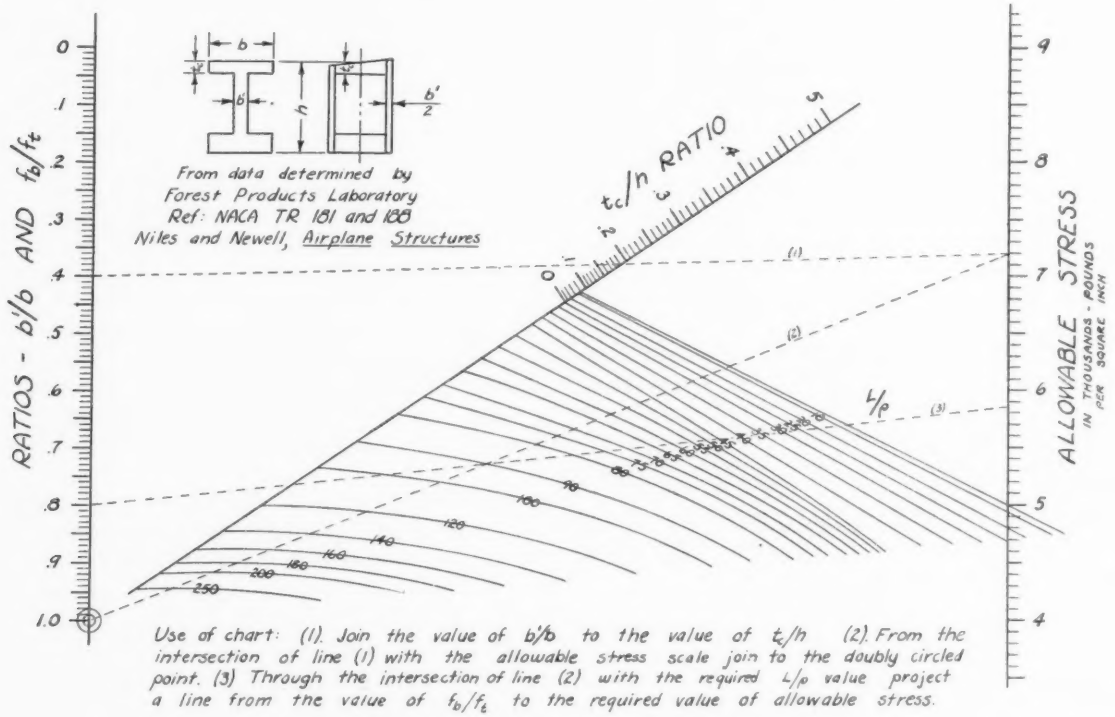

FIG. 1. Allowable stresses for spruce beams in bending and compression.

Use of the Chart

Three types of problems are involved in the use of the chart—one general type and two simplified types. A problem in each will be solved.

I. General type: $b'/b = 0.4$, $t_c/h = 0.19$, $L/\rho = 90.0$, $f_b/f_t = 0.8$.

The solution of this problem is indicated by the dotted lines (1), (2), and (3) in the chart. Line (1) joins the value of b'/b (= 0.4) to that of t_c/h (= 0.19). Locate the intersection of this line (1), with the allowable stress scale. From this intersection point, line (2) joins to the doubly circled point in the lower left corner. Locate the intersection of line (2) with the required L/ρ curve (= 90). Join line (3) from the value of f_b/f_t (= 0.8) through this intersection point and locate the intersection of this line with the allowable stress scale which gives the allowable stress (= 5850 lb./sq.in.).

II. First Special Case: $f_b/f_t = 1.0$, $b'/b = 0.5$, $t_c/h = 0.4$, $L/\rho = 50$ (unnecessary for solution).

When $f_b/f_t = 1$; that is, there is no compression, lines (2) and (3) of the solution will coincide and are both unnecessary since the intersection of line (3) with the allowable stress scale will coincide with that of line (1). Therefore only line (1) is necessary for the solution in this case.

The solution will give an allowable stress equal to 8400 lb./sq.in.

III. Second Special Case: $b'/b = 1.0$, $t_c/h = 0.5$ (unnecessary for the solution), $L/\rho = 80.0$, $f_b/f_t = 0.6$.

When $b'/b = 1.0$; that is, for solid beams, lines (1) and (2) will both coincide with the diagonal line on which the t_c/h scale is given. Therefore line (3) is the only line necessary for the solution and is drawn connecting the value of f_b/f_t to the intersection of the required L/ρ curve with the diagonal line.

The solution will give an allowable stress equal to 5400 lb./sq.in.

Book Reviews

Bearing Metals and Alloys, by Henry Norman Bassett; Edward Arnold & Co., London, Longmans Green & Company, New York, 1937; 428 pages, ill., $8.50.

The above volume may be divided roughly into four parts:

(1) A short history of the development of bearing metals and a discussion of the mechanical problems involved in lubrication of gears and various types of bearings.

(2) A detailed study of white metal bearings including the effects of various constituents on crystal structure and mechanical properties. Approximately one-half of the volume is given over to this study.

(3) A study of copper alloy bearings including the effects on micro structure and physical properties of the various constituents added to copper to form this class of bearings. A very small section is devoted to the type of copper lead bearings in common use in aircraft engines but no mention is made of the application of this bearing to the crankshaft of high-output internal combustion engines.

(4) A section dealing with miscellaneous bearings including rubber, wood, fabric, stone, compressed powder, cast iron, and aluminum.

This book is an attempt to collect and correlate bits of information published at various times by a great number of authors. Much detailed information on many types of bearings is included but no very broad principles of bearing design are developed. The author of the book may perhaps be excused for this treatment since the present state of the art does not seem to permit enunciation of any such principles.

The volume is well indexed and would appear to be more useful as a reference book for detailed problems than as a volume which a mechanical engineer interested in the practical development and design of bearings should read to broaden his viewpoint of the subject.

E. V. Farrar
Wright Aeronautical Corporation

Skywriting, by Lieut. Joseph C. Mackey; The Aircraft Directory, Athens, Ohio, 1937; 63 pages, ill., $1.00.

This booklet describes the difficulties and experiences of the author in attempting to devise a skywriting device which would work, without knowledge of how the original skywriting as done by Major John C. Savage, the English pilot who completed such large contracts in this form of advertising in the United States in 1924.

After discovering a method, Lieutenant Mackey secured a license from the patentees and since then has written in the sky for many advertisers. In the booklet he discloses how his apparatus is designed, the fluid he uses, and his method of tracing his lettering.

Fluid Friction on Smooth Planes

A. F. ZAHM, *Library of Congress*

(Received July 24, 1937)

SUMMARY

Comparison is made of various formulas for the friction of a smooth thin plane in steady translation edgewise through a viscous fluid. Over a wide scale range the formulas agree quite well among themselves and fairly well with the data of many noteworthy experiments, but not with the textbook formulas in use for some decades. Still needed are measurements of skin friction on geometrically similar planes in dynamically similar flow conditions yet further extended and accurately specified.

INTRODUCTION

BEFORE 1901 air friction on wings, hulls, fins, etc., was deemed negligible. Langley, Dines, and Maxim had found it too small to measure with their apparatus, and therefore had reported it imperceptible. On this assumption Hugo Mattullath was developing a commercial twin-hull seaplane of 110-foot span, with all possible loads inside and with the exposed frame excessively sharpened to eliminate pressure drag. Count Zeppelin's airship then was quite long, like a polygonal pencil with pointed ends. Conversely, while these designs offered too much friction, others offered too little. Even after much flying and some wind-tunnel experience, Wilbur Wright deemed skin friction a very minor element of resistance in his biplane. A picture of it in flight, with engine and two men abreast on the wing, seems to justify that opinion. Pressure drag on the wing planes, in his view, was the chief resistance at speeds then prevalent.

EARLY AIR FRICTION STUDIES

The author's skin-friction measurements began early in 1901. At first a ground and polished steel disc, one foot in diameter, was spun in its plane on the shaft of a small electric motor suspended, axis vertical, by a torsion wire fixed to the ceiling. At 1800 r.p.m. the wire was twisted 16° by the plate's air torque and 1.5° by its magnetic torque due to the earth's field. So this "negligible" air force seemed to invite further measurement.

Accordingly, skin-friction planes of various size were supported on a wire balance edgewise in a wind tunnel 6 ft. square by 40 ft. long, having a uniform airstream of adjustable speed. The friction drag, first of smooth and then of rough planes, was measured at various set speeds from 5 to 25 m.p.h. The results were published in a series of papers from 1902 to 1904.[1]

The wind-tunnel laboratory, measuring 30 × 80 ft., was erected at the Catholic University in the winter of 1901, by the National Transit Co., to furnish basic data for aviation and especially for the design of Mattullath's seaplane.

For a given smooth plane so held, in a turbulent flow at said moderate speeds, the mean friction f per unit area, when plotted against the general stream speed v, on logarithmic paper, gave a straight line.

$$f \propto v^m \tag{1}$$

m being a positive constant, and equal to 1.85 for those test conditions. This value of m was verified later in various laboratories. Thence for any other plane in dynamically similar conditions dimensional theory[2] gives

$$f/(\tfrac{1}{2}\rho v^2) \equiv C_f \propto R^{m-2} \tag{2}$$

where $R \equiv vl/\nu$, called the "dynamic scale" or "Reynolds Number." Here l denotes the plane's length; ρ, ν the fluid's density and kinematic viscosity. Thus the dimensionless friction coefficient C_f plots logarithmically against R as a straight line for a moderate range of the dynamic scale.

RECENT AIR FRICTION FORMULAS

For a greater range of scale the test-data graph of C_f against R is concave upward, suggesting the more general formula

$$C_f = aR^{-n} + b \tag{3}$$

a, n, b being suitable constants. As an example, take Fig. 1 in which are plotted extensive friction data judiciously chosen by Dr. Schoenherr. Their mean curve is an accurate graph of

$$C_f = 0.0745R^{-0.218} + 0.00072 \tag{4}$$

in the test range $3 \times 10^5 < R < 4 \times 10^8$.

Instead of Eq. (4) Schoenherr used for this curve

$$0.242/\sqrt{C_f} = \log_{10}(RC_f) \tag{5}$$

which is his version of von Kármán's formula.[3] Table 1 shows more clearly the agreement of these two formulas. Their C_f difference is but a fraction of one

[1] See, *e.g.*, *Atmospheric Friction on Even Surfaces*, Bul. Phil. Soc., Wash., June, 1904.

[2] Lord Rayleigh, Phil. Mag., July, 1904, p. 66.

[3] Karl E. Schoenherr, *Resistance of Flat Surfaces Moving through a Fluid*, Trans. Soc. Nav. Arch. & Mar. Eng., 1932.

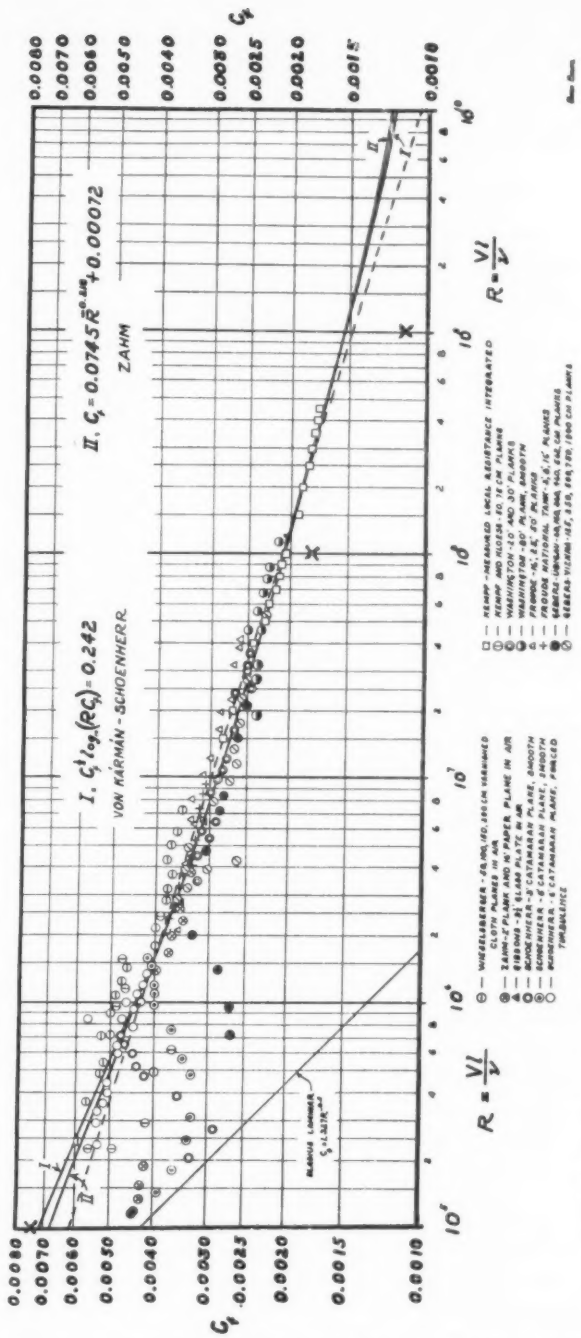

FIG. 1. Friction coefficient C_f *versus* Reynolds Number R for smooth planes.

percent as R varies from 10^6 to 10^9; *viz.*, for nearly all practical aircraft conditions.

As R increases beyond 10^9, C_f approaches 0 by Eq. (5) but asymptotes b by Eq. (3). Which one is closer to actuality remains to be decided by larger-scale data. Some tests indicate that as R increases greatly, C_f tends to a finite limit b. This should be expected if the whole plane drag consists partly of pure friction and partly of body resistance, that is if

$$fS = {}^1/_2\rho v^2 S(aR^{-n} + b) \qquad (6)$$

S being the whole surface and b the coefficient of form resistance. In fact an infinitely thin plane moving edgewise through a free viscous fluid, and dragging a body of adherent boundary fluid at its sides, may not be wholly void of form resistance. A perfect theory would take account of this moving body and the streamlines generated by it.

Of course, the flow at all points near enough to a smooth surface must be entirely parallel thereto, that is laminar, and beget only laminar-shear friction. On a thin enough edgewise-moving plane therefore the whole drag is frictional and none pressural. But if an adhering body of fluid has any form drag this must be transmitted to the laminar layer and thence to the plane, giving it a species of form drag as indicated by b in Eq. (3). Thus, neither turbulence nor adherent fluid can increase the plane's friction except by intensifying the surface shearing velocity gradient, and possibly thereby thinning the sublayer. If such pressure drag occurs it should not be hard to detect by suitable exploration of the pressure drop in the after part of the drifting body fluid. The thinnest friction plane doubtless has a trailing wake behind and a fluid prow before it, as all solid bodies have.

This text takes no account of possible slippage at the surface, especially near the leading edge, which may occur when the plane moves at very high speed through a very viscous fluid. Such flow, disturbing the velocity gradient in the sublayer, would be dynamically dissimilar to that assumed in the present treatment.

As R decreases below 10^6, C_f tends by both formulas to increase without limit, and faster by Eq. (5). Neither expression can long continue close to actuality; both, as the turbulence dies out, must yield to Blasius' well known laminar-flow formula $C_f = 1.327R^{-1/2}$.

Eq. (3) can be derived analytically by assuming

TABLE 1

Coefficient C_f of Mean Skin Friction, by Formulas of Kármán and Zahm for Thin Planes

R	$\sqrt{C_f}\log_{10}(RC_f) = 0.242$	$C_f = 0.0745R^{-0.218} + 0.00072$	Difference, %
10^5	0.0071783	0.0067756	−5.56
10^6	0.0044098	0.0043857	−0.544
10^7	0.0029343	0.0029391	+0.1635
10^8	0.0020720	0.0020632	−0.421
10^9	0.0015306	0.0015331	+0.0318
10^{10}	0.0011973	0.0012122	+1.244

$$dC_f/dR \propto R^{-k} \tag{7}$$

and integrating, k being a constant. The assumption seems plausible and not far different from that of W. Froude and his contemporaries, Stokes, Rayleigh, Reynolds, Calvert, etc. Their qualitative theory of boundary-layer flow along a friction plane was much the same as the present-day theory; *viz.*, the along-stream speed is zero just at the plane and increases with normal distance outward; quite rapidly at the prow but slower and slower with distance aft of it. This waning velocity gradient tends to make $dC_f/dR = 0$ for R sufficiently large, in accordance with Eq. (7). The gradient within the boundary layer for water was fairly well measured by Calvert and others but not adequately derived from the then familiar basic equations of viscous flow. That task was left over for the twentieth century.

Another good alternative to Eq. (5) is Schlichting's formula

$$C_f(\log_{10} R)^{2.58} = 0.455 \tag{8}$$

which plots slightly above the graph of Eq. (5) in Fig. 1. When however its second member is reduced two percent Eq. (8) agrees with Eq. (5) to a fraction of one percent for $10^6 < R < 10^9$, which is now the practical range in aeronautics and marine navigation.

In this large range of R the friction coefficient is not everywhere truly given by the simple equation $C_f \propto R^{-n}$, still found in textbooks. Reference (1), which first demonstrated this formula for air, expressly states that "it cannot be true for a great range of speeds." The most favorable straight line that can be drawn across the unsplit curve in Fig. 1 cuts it at two points and elsewhere departs from it in varying amounts up to about $\pm 0.03C_f$ as R runs from 10^6 to 10^9. This secant line has approximately the equation

$$C_f = 0.03554R^{-0.1582} \tag{9}$$

which may be used when an error varying up to three percent is allowable. Its graph in Fig. 1 is the dashed line.

For closer agreement several secant lines fitting closely various segments of the curve may be employed, as is well known. But a multiplicity of such straight lines cannot be simpler than the single curve (4) which they may each approximate at a different segment. Because of a possible error up to three percent or more all friction formulas of the simple type of Eq. (9) for wide-range use may well be discarded. For instance, the theoretically derived formula $C_f = 0.074R^{-0.2}$, as delineated by the x's in Fig. 1, undershoots the mark from 0 to 38 percent as R runs from 10^7 to 10^{10}. Too often technicians must use an empirical formula correct for actual conditions rather than a rational one correct for assumed conditions. Happy is the theorist with ample premises.

If Eq. (4), (5), or (8) shall prove accurate enough, it can easily be used in tabular form, made once and for all to any degree of precision required for practical computation. The present need is not more accordant formulas than are Eqs. (4) and (5) in the range $10^6 < R < 10^9$, but more accordant and more extended data on which to base them.

Early Applications of Skin-Friction Data

The quantitative division of airfoil drag into two parts, induced and profile, was first published by the author in his cited pamphlet of 1904.[1] For a thin plane wing of area S, at small incidence α, the profile or frictional drag is

$$D_p = fS = aR^mS$$

The induced or pressural drag was shown to be

$$D_i = L \tan \alpha = L^2/2k\rho Sv^2$$

where $\tan \alpha = L/2k\rho Sv^2$ was taken from Duchemin's formula. Thus the total wing drag was written

$$D = L^2/2k\rho Sv^2 + aR^mS \tag{10}$$

L being the lift, k a dimensionless coefficient. The drag form $L \tan \alpha$ was published by Sir George Cayley in 1809; the form $L^2/2k\rho Sv^2$ was given in the author's report to the Philosophical Society of Washington, February 27, 1904, and published in its Bulletin, Vol. 14; also in technical journals here and abroad. Textbooks now commonly call it "induced drag."

From estimates of resultant pressure and friction it followed that minimum-drag bodies, say struts, hulls, etc., cannot be very long because the drop in pressure drag is more than countered by the increase in friction. Thus, the advantage of fish forms for air and land vehicles was explained. An airship with two-caliber bow and nine-caliber stern was proposed to replace the prevailing types. Presently that form came into use, as seen in the Graf Zeppelin and in the R-34, first airship to cross the Atlantic. Eq. (10) also showed that thin wings at small incidence have much more friction drag than pressure drag.

Conclusion

Now the chief resistance to high-speed aircraft is friction. The present problem is not only to analyze but also to reduce it. Some try by removing the boundary layer, others by weakening its viscous strength. Their moderate success has not yet materially improved aeronautic design.

In conclusion, the author wishes to thank Dr. Schoenherr for the use of his original diagram, and Owen Evans for preparing from it the present abridged diagram and for helping to compute the values in Table 1. The abridgement omits some of the copious data not essential to outline truly the mean graph or the scope of each author's measurements; its C_f scale is enlarged three-fold to ensure better separation of the closely coincident graphs.

Variation of the Modulus of Elasticity of Duralumin

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(Received July 21, 1937)

IN THE strict use of the term modulus of elasticity, one means the ratio of stress within the proportional limit to corresponding strain. This property, as thus defined, is a constant for each kind of material; and in tension or compression is usually designated by the symbol E. The modulus of elasticity is a measure of the stiffness of a material or its ability to resist change of shape under stresses not higher than the proportional limit.

In a more general form, the modulus of elasticity is the slope of the stress-strain curve at any stress. By definition:

Modulus of Elasticity or Young's Modulus = stress ÷ strain. Above the proportional limit, the slope of the stress-strain curve is sometimes called the reduced modulus and denoted by E_σ.

Probably the most important physical property of any material to the engineer is this ratio of stress to strain. In all stress-analysis work, the modulus of elasticity is taken as a constant; however, this paper will attempt to show that in the very range in which the engineer is most interested, the modulus varies a great deal. The variation of the value of E within individual alloy systems has been discussed by R. L. Templin and D. A. Paul.[1] In their paper they discuss the changes of modulus produced by addition of alloying elements, but none of their work refers to the modulus above the proportional limit.

Since in airplane structures a great many of the failures and critical loads are a function of the stability of the member, the ratio of stress to strain is of primary importance, for the stability of any member is directly proportional to this ratio. For example, if one considers an axially compressed member with hinged ends, then in discussing the elastic stability of such a member, it is assumed that the member has a small deflection, and the force that is necessary to keep the bar in this slightly bent shape is calculated. If the deflection is very small, the resulting bending stresses are very small in comparison with the compressive stress, and the relation between bending stress and bending strain is given by the modulus E_σ, if the compressive stress is above the proportional limit. By assuming that the cross-section of the member stays plane during the bending, the equation of the deflection curve will be the same as in the case of materials following Hooke's law, except that E_σ will replace E. Thus the critical load will be given by

$$P_{cr} = \pi^2 E_\sigma I/l^2$$

or the critical stress will be

$$\sigma_{cr} = \pi^2 E_\sigma (r/l)^2$$

Another example is the critical stress of a curved sheet under compression in which, below the proportional limit, $\sigma_{cr} = KE(t/R)$, and above the proportional limit, $\sigma_{cr} = KE_\sigma(t/R)$. These two examples indicate that in all stability equations the equations hold for stress above the porportional limit if the value of the modulus for the corresponding stress is substituted in the equations. This is only strictly true if the deflections stay small.

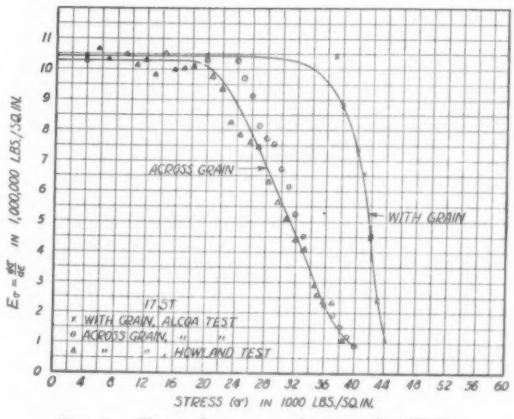

FIG. 1. Slope of stress-strain curve for 17ST.

If the stress-strain diagram for a material is known, then E_σ can be obtained as a function of σ by measuring the slope at every point. The author has done this for four different aluminum alloys: 17ST, 17SRT, 24ST, and 24SRT, both with and across the grain, *i.e.*, with major stress in and perpendicular to the direction of rolling, respectively.

Fig. 1 shows the change of E_σ with stress. The two curves indicate the difference in ability of the material to resist stress when it is applied with and across the grain. It will be noted that at 35,000 lbs. per sq.in., there is a factor of 3.5 difference in the value of E_σ; this stress value being the defined yield point of 17ST (defined yield point is 0.2 per cent permanent set). It has long been known that there was a difference between the two directions, but the author believes

[1] R. L. Templin and D. C. Paul, *Modulus of Elasticity of Aluminum Alloys*, Inst. of Metals, 1931, page 480.

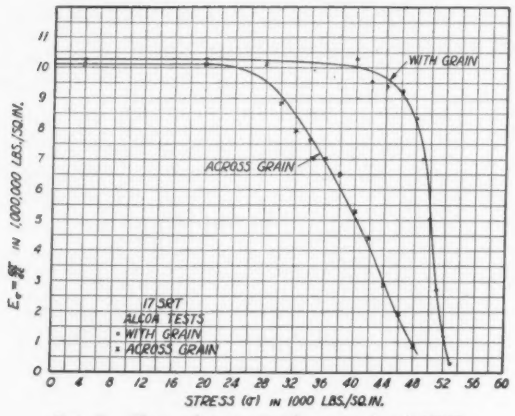

FIG. 2. Slope of stress-strain curve for 17SRT.

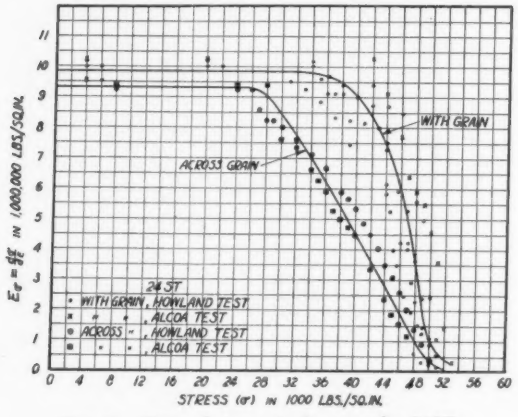

FIG. 3. Slope of stress-strain curve for 24ST.

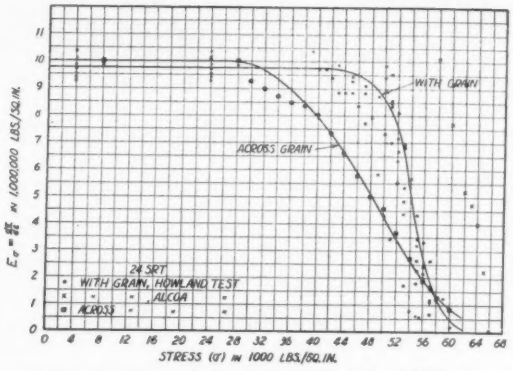

FIG. 4. Slope of stress-strain curve for 24SRT.

TABLE 1

Material	Defined Yield Point	Value of E_σ with Grain	Value of E_σ across Grain	Ratio of E_σ's
17ST	35,000	9.8×10^6 lbs./sq.in.	2.75×10^6 lbs./sq.in.	3.57
17SRT	46,000	9.2×10^6 lbs./sq.in.	1.90×10^6 lbs./sq.in.	4.84
24ST	43,000	8.0×10^6 lbs./sq.in.	3.25×10^6 lbs./sq.in.	2.46
24SRT	53,000	6.8×10^6 lbs./sq.in.	3.00×10^6 lbs./sq.in.	2.26

that the serious effect of this variation on stability failures has not been fully realized.

Figs. 2, 3, and 4 are similar to Fig. 1, showing the change of E_σ with stress for 17SRT, 24ST, and 24SRT, respectively. The large number of points was obtained by taking the slopes from a number of stress-strain curves run under similar conditions. The tension specimens used were standard shape and each test was made with one Huggenberger tensometer (300 mag.) on each side of the specimen. The loads were applied in a 3000-lb. Riehle Bros. testing machine.

As is seen, considerable scatter is obtained, but this is to be expected when dealing with a material in the plastic region. The curves are faired through average points for a given stress, thereby the curve indicates the average value of E_σ for each value of stress.

Table 1 shows the variation of E_σ for the various defined yield points as obtained from Figs. 1, 2, 3, and 4. The reason for the consistent fall-off in the value of E_σ with the grain at the defined yield point is that the break in the stress-strain curve becomes sharper as the strength of the material increases (see Fig. 5). In Fig. 5 is seen an example of two stress-strain curves showing the variation in slope of the curve at the defined yield point.

The author believes that the curves in Figs. 1, 2, 3, and 4 represent satisfactory average values because of the interesting set of curves which results if all of the "with the grain" curves are plotted up on one figure (see Fig. 6). It should be noticed that the shape of 17ST and 17SRT is similar, and that 24ST and 24SRT are similar; also that 17SRT has a slightly lower average E than 17ST and the same thing is true for 24SRT and 24ST.

CAUSE OF SCATTER IN STRUCTURAL TESTS

Experimental scatter is undoubtedly caused by a large number of variables. General setup, speed of loading, physical dimensions of material, and human factor all play their part in nearly every structural test. However, something more basic than these mentioned is the stress-strain behavior of the material. For example, when the compressive stress in a member of a materia' which has a definite yield point approaches this value, the member will become unstable and fail; that is, if the yield point is actually a "point" where the material changes length with no increase in stress ($E = 0$). It would not be possible for the compressive stress to go above this value. In dealing with dural, there is no such ideal material from a stress analysis standpoint. Instead one has a material which has nearly a constant E_σ up to 20 or 25 thousand lbs. per sq.in., and above this there is a gradual decrease until roughly 40,000 lbs. per sq.in. Above 35 or 40 thousand lb. per sq.in. the decrease in slope is very rapid. This means that in a structural test where the stresses get up into this high region, there is no definite point of instability but rather a general decrease in stability.

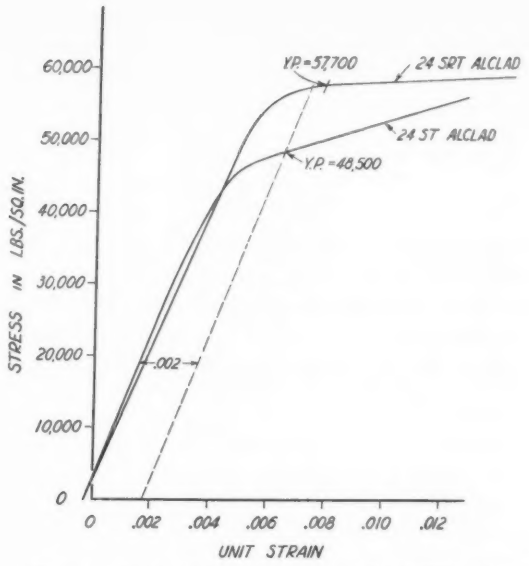

FIG. 5. Typical stress-strain curves for 24ST and 24SRT.

Within certain limits the failure of duralumin parts is problematical, that is if two compression members are made as nearly alike as possible, the chances of their becoming unstable at the same stress is very small. On the other hand, if the material had a definite yield point (strict sense), then the two specimens might fail at the same stress, at least the chance is much greater assuming that other factors stay the same. In other words, even with the greatest care in making and setting up a duralumin structural specimen, variations of several percent in the failure stress of similar specimens are not only likely but probable.

CAUSE OF DISAGREEMENT OF EXPERIMENT AND THEORY

In a large number of papers on experimental light alloy work, the author has noticed that experimental curves have been drawn up for an elastic failure phenomenon, and somewhere on the same sheet will be a theoretical curve based on the yield point. Apparently, the author of the paper forgot for the moment that a yield point failure is not an elastic failure but an inelastic failure (by definition yield point is 0.2 percent permanent set).

Also, it is very important for the research man and the stress analyst to realize that there is no physical reason why a compression member should fail at the defined yield point. Nothing physical happens to the material at the defined yield point. In some steels the yield point is a definite stress which is important

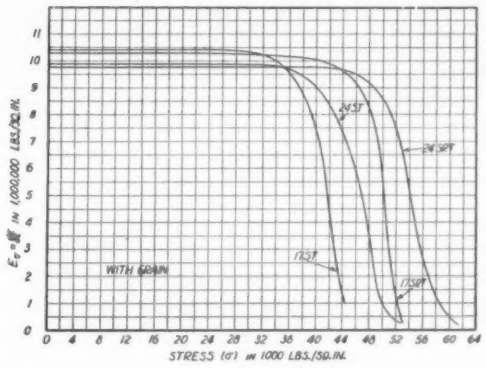

FIG. 6. Variation of E_σ for different materials stressed with the grain (direction of rolling).

from a stress-analysis viewpoint and even more so to the research student. However, the author believes that a large number of men have unknowingly or unintentionally adapted the important and convenient conception of yield point, valid for some steels, to the light alloys. It is unfortunate that the term yield point was given that stress at which there is 0.2 percent permanent set, for it promotes false ideas. The reasons for using a defined yield point have been given by R. L. Templin.[2]

Theoretical men dealing with structures of light alloys should remember that none of the light alloys have any definite stress at which members in compression must fail. The stress analyst should not substitute in the same equation a yield point stress and a modulus of elasticity which holds below the proportional limit.

CONCLUSION

This paper gives curves for the variation of E_σ for four light alloys, 17ST, 17SRT, 24ST, and 24SRT, plotted against stress. These curves are important in that they show that the average value of E_σ has no sudden changes, so that at no particular stress can one be sure of an inelastic failure of a member. Defined yield point is an interesting method of comparing two metals, but it is of no value or help in solving many of the problems of the research student or the stress analyst. If the stress analyst uses the defined yield point in calculations, he should use the correct values of E_σ taken from the curves, whenever inelastic failures are involved.

[2] R. L. Templin, *The Determination and Significance of the Proportional Limit in the Testing of Metals*, A.S.T.M., Vol. 29, 1929, page 523.

On the Transfer of Stress in Metal Sheet Covered Beams

TUNG-HUA LIN, *Nanking, China*

(Received June 30, 1937)

IN THE Lovett and Rodee paper on "Transfer of Stress from Main Beams to Intermediate Stiffeners," published in the October, 1936 issue of this JOURNAL (Volume 3, Number 12), the value of the ratio of the effective modulus of rigidity to the modulus of elasticity, G'/E, as calculated in the paper, is much lower than the theoretical. This is mainly due to the neglecting of the effect of the sheet in taking compressive stress in the effective width. Due to the fact that the sheet adjacent to the spar takes compression with the spar (assuming the stress intensity in the effective width of the sheet the same as that of the spar), as the spar transfers some compressive stress to the adjacent stiffener, the sheet transfers some of its stress too; so the shear stress or shear strain will increase with the distance from the center of the spar up to the end of the effective width. At the center of the panel, the sheet takes almost no direct stress, so the shear stress over that portion is constant. By the same reasoning, as the effective width of stiffener No. 1, (see Fig. 2) is approached, the shear strain decreases up to the center of the stiffener. A straight line, MN, perpendicular to the axis of the spar on the top surface before loading, will be a curved line, $AFGB$, after loading. The shear strain used in figuring G'/E is the average shear strain across the spar to the stiffener, *i.e.*, the slope of the dotted line AB. So the corresponding amount of sheet to be included in the effective area for the spar and the stiffener, should be up to the points F and G, respectively, where the slope of the curve $AFGB$ equals the slope of the dotted line AB. This amount of sheet between A and F or G and B varies from $C/2$ to C, depending upon the ratio of the effective width of sheet in taking compression to the total width of the panel. (C is the effective width of the sheet in taking compression.) In the following, the sheet thickness is only 0.025 in., and the distance between the spar and the stiffeners is from 5 in. to $5^1/_2$ in. The effective width is small as compared to the total panel width, so it would involve little error to assume that the whole effective width is included in the effective area.

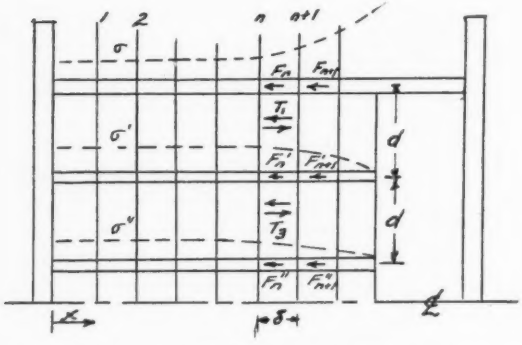

FIG. 1. Compression and shear forces on main spar and stiffeners.

From Fig. 6 of the Lovett and Rodee paper, that is reproduced in part in Fig. 4 of this paper, the following figures are scaled; (M_0 = applied moment = 120,000 in. lbs.).

Dist. from Fixed End in Inches	σ Stress in Spar lbs./in.^{2}	σ'' Stress in Stiffener 2 lb./in.^{2}	$\frac{\sigma - \sigma''}{2000}$
0	9600	9600	0
10	9600	9500	0.05
20	9700	9300	0.20
30	9800	8900	0.43
35	9850	8600	
40	10100	7900	1.10
45	10350	7100	
50	10800	6100	2.30
55	11250	4800	
60	12000	3500	4.25
65	12850	2050	

t = thickness of sheet = 0.025 in.
μ = Poisson's ratio = 0.3 for dural
$2C = \sqrt{E\pi^2t^2/3(1-\mu^2)\sigma}$ $E = 10^7$ lbs./in.^{2}
$2Ct = 3.77/\sqrt{\sigma}$
T = shearing forces shown in Fig. 1

A, A', and A'' are effective areas of the spar, stiffener 1 and stiffener 2, respectively.

σ, σ', and σ'' are the stresses in the spar and stiffeners 1 and 2, respectively.

$$T_1 = A(\sigma_{n+1} - \sigma_n) = G_1\gamma_1\delta t$$
$$T_2 = A''(\sigma_n'' - \sigma_{n+1}'') = G_2\gamma_2\delta t$$

Let $G_1\gamma_1\delta t + G_2\gamma_2\delta t = G'(\gamma_1 + \gamma_2)\delta t$

γ_1 and γ_2 are the shear strains between the spar and stiffener 1 and that between stiffeners 1 and 2, respectively.

$$\gamma_1 + \gamma_2 = \int_0^x (\sigma - \sigma'')dx/Eb$$

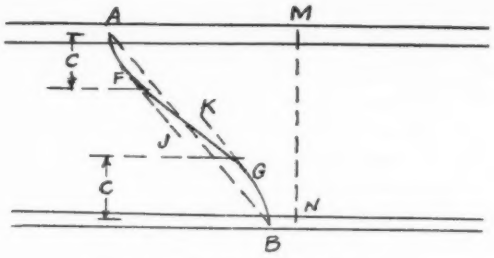

FIG. 2. Shear curve after loading.

where b = distance between spar and stiffener 1 or between adjacent stiffeners, (average value of $b = 5.25$ in.).

$$\frac{G'}{E} = \frac{A(\sigma_{n+1} - \sigma_n) + A''(\sigma_n'' - \sigma_{n+1}'')}{lb \int (\sigma - \sigma'')dx} b$$

Dist. from fixed end, in.	40	50	60
$\int(\sigma - \sigma'')dx$ (reference 1), in. lbs.	24100	56500	120,000
σ, lb./in.^{2}	10100	10800	12000
0.5×0.025 (reference 2)	0.0125	0.0125	0.0125
Spar flange area	0.568	0.568	0.568
Ct	0.0188	0.0181	0.0172
A	0.5993	0.5986	0.5977
σ'', lb./in.^{2}	7900	6100	3500
$2Ct$	0.042	0.0484	0.064
Area of stiffener	0.044	0.044	0.044
A''	0.086	0.0924	0.108
$\sigma_{n+1} - \sigma_n$, lb./in.^{2}	500	900	1600
$\sigma_{n+1}'' - \sigma_n''$, lb./in.^{2}	1500	2300	2750
$A(\sigma_{n+1} - \sigma_n)$, lbs.	300	539	956
$A''(\sigma_{n+1}'' - \sigma_n'')$, lbs.	129	212	297
$A(\sigma_{n+1} - \sigma_n) + A''(\sigma_n'' - \sigma_{n+1}'')$	429	751	1253
$\frac{G'}{E}$ from above equation =	0.374	0.279	0.220

[1] Obtained by Simpson's Method of Integration.

[2] Consider 1/2 in. on the edge side of the rivet line on the spar.

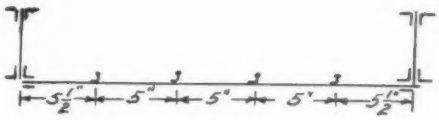

FIG. 3. Test specimen.

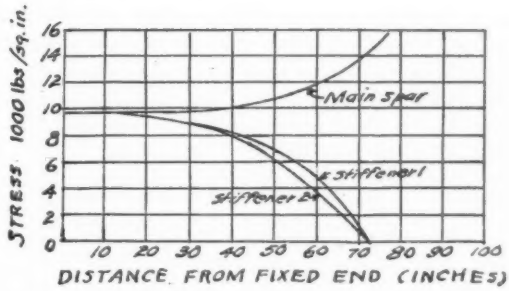

FIG. 4. Stress distribution for M_0 = 120,000 in. lbs., sheet thickness, .025 in.

The theoretical value of G'/E varies from 0.385 to 0.250. The above computed value of G'/E varies from 0.384 to 0.220, which is much nearer to the theoretical value than those computed in the Lovett and Rodee paper. Since the stiffener area is small, it would cause a large error to neglect the effective width of the sheet.

The discrepancy between the theoretical value and the computed may be due to the following causes:

(1) The angle of inclination of the wrinkle is not exactly 45°, so the value of G'/E would be less than 0.250.

(2) There may be some slip in the rivets. This would give a lower value of G'/E.

(3) The sheet after buckling still carries some compressive stress across the direction of wrinkling. This would give the theoretical minimum value of G'/E a little over 0.250. For thin sheet this effect is small.

The combined effect of the above three factors should account for the discrepancy.

Fifth Anniversary of the Institute

THE Roster of Members which was mailed to members of the Institute with the last issue of the Journal has given them a better idea than statistical tables how the Institute has grown in numbers since its organization on October 15, 1932. To supplement the lists given in the Roster, it will also be interesting to know how broadly the membership is spread geographically. The following compilation shows the membership by states and in twenty-five foreign countries.

Alabama	2	Kansas	7	New York	392
Arizona	2	Kentucky	1	North Carolina	3
California	213	Louisiana	12	Ohio	64
Connecticut	68	Maryland	50	Oregon	2
Delaware	1	Massachusetts	97	Pennsylvania	78
D. of C.	58	Michigan	168	Rhode Island	3
Florida	8	Minnesota	45	Texas	3
Georgia	34	Missouri	14	Vermont	3
Illinois	24	New Hampshire	2	Virginia	36
Indiana	77	New Mexico	1	Washington	20
Iowa	1	New Jersey	75	U. S. Possessions	6

Australia	3	France	29	Poland	4
Austria	3	Germany	38	Scotland	1
Belgium	2	Holland	9	South Africa	1
Brazil	4	India	1	Sweden	3
Canada	16	Italy	19	Switzerland	5
China	5	Japan	10	Turkey	2
Czechoslovakia	4	Latvia	1	U. S. S. R.	1
England	59	Norway	2	Venezuela	1
		Peru	2		

No better commentary on the soundness of the plan and purposes of the Institute could be secured than from these lists. Some of the newer members will be interested on this Fifth Anniversary month to know about the formation of the Institute and what it has accomplished.

ORGANIZATION

About ten years ago several American aeronautical specialists who had been honored by membership in the Royal Aeronatical Society of Great Britain discussed the possibility of forming a similar society in the United States.

The fullest information as to the organization of the British society was courteously furnished by its officers. For various reasons, the formation of the society was delayed.

In September, 1932, after a preliminary discussion, Charles L. Lawrance invited several of those who had indicated an interest in the plan to have lunch with him at the Yale Club and discuss the proposed incorporation. Several days later an organization meeting was held. Those participating in these meetings were Dr. J. C. Hunsaker, Charles L. Lawrance, Grover Loening, E. E. Aldrin, E. P. Warner, Colonel V. E. Clark, Earl D. Osborn, and Major Lester D. Gardner. It was decided to have incorporation papers prepared and filed.

This was done in Albany on October 15, 1937, so that that day will always be the anniversary date on which celebrations may be held as years pass and the reputation of the Institute becomes still greater through growth of membership and accomplishments.

At the first meeting of the incorporators, it was decided to call the required Board of Directors, The Council. Temporary officers were elected. President, J. C. Hunsaker; Vice Presidents, Grover Loening, E. P. Warner; Treasurer, Charles L. Lawrance; and Secretary, Lester D. Gardner. The membership of the first Council in addition to the above included E. E. Aldrin, J. S. Ames, V. E. Clark, James H. Doolittle, George J. Mead, Clark B. Millikan, C.-G. Rossby, and T. P. Wright.

No special fund was available for the organization expense and as it was not advisable to ask for gifts, the Secretary was requested to use his home address as the address of the Institute and to spend no more money than received from dues of Founder Members.

The question of a name for the new society presented difficulties. There had been an Aeronautical Society which was later the Aeronautic Society of New York and still later, in 1908, was changed to the Aeronautical Society of America. There had also been an American Society of Aeronautic Engineers. It was difficult to select an all inclusive name as it was the intention of the organizers to have as members those engaged in aeronautical scientific work as well as aeronautical engineers and technicians. E. P. Warner suggested the name which was finally adopted.

GRADES OF MEMBERSHIP

Following the plan of the R.Ae.S. and other scientific societies the membership was to be graded. Immediately there arose the delicate question as to who was to do the grading. After much discussion it was decided to secure members first and then decide how they were to be graded. About four hundred names were proposed and the Secretary sent invitations to this list inviting them to become members. Two tentative grades were designated. Scientific Members were those who were engaged in instruction, research, or other scientific activities. Engineering Members were those who were engaged in the industrial application of aeronautics. Later, this overlapping and confusing division was abolished and all these members became Associate Fellows or Fellows.

In considering the list of names of prospective members it was found that many well known aeronautical specialists who would make desirable members could not properly be graded as Scientific or Engineering members. A happy solution of this problem was found

by creating the grades of Industrial and Pilot Members. The purpose of broadening the membership of a scientific society was to have present at meetings men who could discuss the practicability of aeronautical proposals from the standpoints of costs, manufacture, and operation. A group of distinguished foreign aeronautical workers and engineers were invited to become members without dues.

Later it was found that many younger men as well as those who did not have the qualifications for the other grades wished to join the Institute and the grade of Technical Member was created. A committee has been appointed by the Council to consider further changes in the grades and their qualifications to meet the expanding membership needs.

Many requests were received from schools, universities, and students of aeronautics for the creation of a grade of Student Member. Knowing that many students could not afford to pay even the low membership dues of the Institute, the Council decided to make it possible for students to organize Student Branches and receive the Journal for nominal dues of $1 a year. This was regarded as a contribution of the Institute to students during their years of preparatory aeronautical education.

The Journal

In January, 1934, it was decided to publish a Journal which would print contributions of scientific and technical interests to members and others. As it was impossible to pay for the printing of the Journal from the dues received, advertising was accepted for the first two years. As all the editorial work had to be done by voluntary assistance from members, it was only possible to publish a quarterly. Dr. J. C. Hunsaker became editor and with the assistance of an Editorial Board has edited the Journal for four years. Soon, it is hoped, an editor may be employed who can relieve Dr. Hunsaker of much of the work he has done so ably. Gradually the demand for the publication of more papers caused the change from a quarterly to a bi-monthly and finally in January, 1936, to a monthly. A further enlargement was made by increasing the size of the pages. The increase in the number of subscribers who are not members of the Institute indicates the opinion that others have of the quality of the contents of the Journal. The Journal goes to 41 foreign countries and has contributed additional prestige to the technical standards of American aeronautical procedure.

Corporate Membership

The revenue received from advertisements in the Journal paid for the costs of printing the issues, but the securing of orders and copy and the printing of extra pages appreciably reduced the amount available for printing editorial matter.

The President of one of the large aircraft companies suggested that instead of contributing to the cost of the publishing of the Journal through advertising with the resulting expense of preparation and printing the extra pages, that the Institute create a grade of Corporate Members so that those companies wishing to contribute to the cost of the Journal could do so directly through the payment of dues. The proposal was adopted, the printing of advertising discontinued, and the editorial pages of the Journal increased in number. Some of these pages were used for the printing of the "Aeronautical Reviews" which are abstracted from the Technical Data Digest prepared by Wright Field.

Branches

When the Institute was organized, it adopted many of the ideas which had been found to be successful in the operation of the Royal Aeronautical Society of Great Britain—the oldest aeronautical society in the world.

The R.Ae.S. has organized many branches in various parts of the British Empire. Membership in these branches does not require the examination or other qualifications for membership in the parent organization.

There are many persons who are not eligible for membership in the Institute who may wish to affiliate with a group interested in the advancement of the aeronautical sciences. There may be others who are eligible for membership in the Institute but for financial or other reasons do not wish to become members of the national organization. It is for these, as well as for regular members, that Branches will be sponsored by the Institute.

By holding meetings in various localities, those interested in the advancement of the aeronautical sciences will be given an opportunity to hear speakers and participate in discussions which will be helpful to them in their work. The lectures will be of a practical nature so that they will be readily understood by those who have no specialized technical training. Through meetings and social gatherings, members of the Branches will become acquainted with others engaged in similar work as well as with those in their locality interested in developments in other fields of aeronautics than their own. It will enable members of the Branch to receive invitations to attend meetings of other organizations.

The Institute will act, with no expense to the Branches, as a central agency for the preparation of programs, securing speakers, and providing coordinating supervision which should be helpful to the various Branches. Members of a Branch will be entitled to attend all general lectures and meetings of the Institute so far as it is practicable to accommodate them. They will also be given use of the Institute Library and Aeronautical Index. A Bulletin will be issued which will

be sent to all Members and Affiliates to keep them in touch with the activities of Branches.

The purpose of the Institute in organizing these Branches is to provide the expanding aeronautical profession with local interests to supplement the broad general activities of the national society. Through Branch membership, workers in various fields which come within the scope of the aeronautical sciences will become familiar with the general purposes of the Institute, and, it is hoped, will recognize the value of membership in the Institute.

Finances

From its organization, the Institute has been operated within its income. No activities have been undertaken the expense of which would exceed the estimated budget of the year. The members have only been required to pay about one third the operating expenses of the Institute. The other revenue for expenses has come from advertising, Corporate Memberships, and Benefactor Members.

Benefactor Members

When the Institute needed an office and clerical assistance the funds for this additional service were secured by inviting several companies and persons to become Benefactor Members, which is limited to those who have contributed $1000 or more to the Institute. Several companies that later contributed as Corporate Members became Benefactor Members. The following members have each made generous contributions to the Institute: E. L. Cord, D. W. Douglas, R. H. Fleet, Grover Loening, Glenn L. Martin, George J. Mead, and Sherman M. Fairchild.

The Skyport

After a year without an office, an offer came through Major E. E. Aldrin to occupy space in the great RCA Building in Rockefeller Center. The management thought that it would be a logical center for aeronautics as well as radio and believed that having the Institute there would assist in accomplishing this aim. The success of this generous offer has become apparent and is appreciatively recognized by the owners of this great enterprise. The Manufacturer's Aircraft Association, The Aeronautical Chamber of Commerce of America, The Curtiss-Wright Corporation, Sperry, Bendix and Fairchild are among those who have headquarters in Radio City.

When the offer was made, the Institute had only a small amount of money in the bank. Grover Loening generously offered to furnish and equip the Skyport as a combination office and clubroom. Visitors, particularly those from abroad, have praised the remarkable view from the 54th floor as well as the murals which Mr. Loening presented.

The Aeronautical Index

Three years ago the Institute was provided with workers by the Works Progress Administration to prepare an aeronautical card index. This has expanded so that it now has over 600,000 cards containing several million references. It is believed to be the most comprehensive index of aeronautics in existence. So that this vast compilation might be available in part, at least, to other organizations, the W.P.A. expanded the project so that nearly one hundred workers became available and a set of Bibliographies on a selected list of aeronautical subjects could be prepared. Fourteen have been completed and about twenty more will be issued. The cost of this work has been over $150,000 and could never have been done without governmental aid. Every experienced aeronautical engineer or scientist who has examined the Index has agreed that the results reflect great credit on the workers provided by the W.P.A.

Awards

The Institute has been made the custodian of two funds to provide cash awards and a certificate for achievements in aeronautics.

Dr. S. A. Reed bequeathed the Institute $10,000 to endow the Sylvanus Albert Reed Award "for a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations, the beneficial influence of which on the development of practical aeronautics is apparent."

The brothers and sister of Lawrence B. Sperry have established a fund which they have agreed to increase until it amounts to $10,000 to provide a cash award and a certificate "for a notable contribution made by a young man to the advancement of aeronautics."

No greater evidence of confidence in the permanence of the Institute could be presented than making it the custodian of these funds.

The Future

There are many other activities of the Institute that could be described but the above summary will give a general idea of how the Institute started and has expanded. The officers and the Council as well as the members can look forward to the future with confidence as the work of the Institute becomes even better known. The small library needs additional books. The staff needs additional assistants to carry forward the many activities that could be undertaken. The Journal should be enlarged to provide for a more comprehensive presentation of aeronautical, scientific, and engineering advances. An endowment fund should be secured and when possible, a building erected to provide for an adequate library, meeting rooms, editorial offices, index, and executive offices.

That these are not impossible is evidenced by the fact that a friend has made a bequest to the Institute in his will of securities having a value of five hundred thousand dollars. Others will undoubtedly wish to make bequests to the Institute of substantial amounts or make immediate contributions to the Endowment Fund or for special purposes. The Royal Aeronautical Society of Great Britian has had a distinguished record of achievements for sixty-eight years. In the first five years of its history the Institute of the Aeronautical Sciences has only started to render many of the services that are within its scope.

LESTER D. GARDNER

Institute Notes

LUNCHEON IN HONOR OF GROUP CAPTAIN GEORGE C. PIRIE

About thirty members of the Institute attended a luncheon in honor of Group Captain George C. Pirie, M.C., D.F.C., of the Royal Air Force of Great Britain, who will this month succeed Air Commodore T. E. B. Howe as British Air Attache in Washington.

Air Commodore Howe, who has made so many friends in aeronautical circles by his constant attendance at meetings of the Institute as well as other organizations, will command a Fighter Group in the North of England on his return.

Group Captain Pirie had had an interesting career in the Royal Air Force. Since 1934 he has been with the Directorate of Operations of the Air Staff of the R.A.F.

VISITORS TO THE INSTITUTE

J. C. Hodgson, an Honorary Fellow of the Royal Aeronautical Society and author of the "History of Aeronautics in Great Britain," as well as other books on the history of aviation, visited the Institute recently. He is visiting many of the leading libraries in the East to see their collections of rare volumes. He is one of the best known English authorities on rare books.

Among other recent foreign visitors to the Institute were Josef Rückert of the D.V.L., of Adlershof-Berlin, Germany; Captain R. Louis, Supermarine (Vickers) Ltd., Southampton, England; Fritz Jadicke, Managing Director, Pintch, Berlin, Germany; Captain C. H. Scott, Flying Superintendent, Australian National Airways; Captain Geoffrey F. Woolf of the Royal Air Force Club, London, England; and Werner Wenzel, Junkers Flugzeugwerke, Dessau, Germany.

INSTITUTE MEETINGS

December 17, 1937. The Wright Brothers Lecture by Professor B. Melvill Jones of Cambridge University, Cambridge, England. Annual Dinner and Honors Night. Conferring of Honorary Fellowships, presentation of Daniel Guggenheim Medal, Sylvanus Albert Reed Award, and Lawrence Sperry Award.

December 21, 1937. Wright Brothers Lecture repeated by Professor B. Melvill Jones at the California Institute of Technology, Pasadena, California.

December 27–30, 1937. Institute Meeting as part of Annual Meeting of the American Association for the Advancement of Science, Indianapolis, Indiana.

January 24–26, 1938. Annual Technical Meeting of the Institute of the Aeronautical Sciences, Columbia University, New York.

February 11, 1938. Pacific Coast Branch Meeting.

June 28–30, 1938. Institute Meeting as part of Summer Meeting of the American Association of the Advancement of Science, Ottawa, Canada.

September 12–16, 1938. International Congress for Applied Mechanics, Massachusetts Institute of Technology, Cambridge, Massachusetts.

FIFTH INTERNATIONAL CONGRESS FOR APPLIED MECHANICS

The Fifth International Congress for Applied Mechanics will be held at the Massachusetts Institute of Technology at Cambridge, Massachusetts, on September 12 through 16, 1938. The Institute of the Aeronautical Sciences has been requested to assist in welcoming the delegates on their visit to New York. At the close of the meeting the members are expected to proceed to Washington and also to visit the Langley Memorial Laboratory at Langley Field, Virginia.

The work of the Congress will be accomplished by means of technical sessions at which communications from members will be read and discussed. The field of Applied Mechanics will be divided into the following general heads:

I. Structures, Elasticity, Plasticity, Fatigue, Strength Theory, Crystal Structure.
II. Hydro and Aerodynamics, Gasdynamics, Hydraulics, Meteorology, Water Waves, Heat Transfer.
III. Dynamics of Solids, Vibration and Sound, Friction and Lubrication, Wear and Seizure.

Besides communications from members, it is planned to have a number of General Lectures, as at former Congresses, for which the separate technical sessions will be suspended.

Dr. J. C. Hunsaker of the Massachusetts Institute of Technology, and Dr. Th. von Kármán of the California Institute of Technology, are Joint Secretaries of the Congress. It is requested that those expecting to attend the Congress transmit to the Secretary their addresses, together with the field of Applied Mechanics in which a communication is contemplated, in order that they may be sent future notices. These communications should be addressed to:

Fifth International Congress for Applied Mechanics
Massachusetts Institute of Technology
Cambridge, Massachusetts, U. S. A.

Personnel Opportunities

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Available

Young Graduate Engineer. 3 years industrial engineering experience, (time and motor study, management problems, etc.) and two years in the aeronautical industry in design and stress analysis. At present employed in design engineering in the aeronautical industry but desires a change to a technical sales engineering position which requires a somewhat unusual combination of education, personal traits and experience in the aeronautical industry. Write Box 67, Institute of the Aeronautical Sciences.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Calculation of a Multiplane with an Infinite Number of Thin Wings. E. Pistolesi. Flow around an infinite number of thin wings for vertical, tandem and oblique arrangements. Equations are developed for distribution of vorticity along the profile, and the distribution of induced velocity lift, moment and form of profile are deduced. Method followed is an extension of the Birnbaum-Glauert procedure for the isolated wing. L'Aerotecnica, June, 1937, pages 484–506, 7 illus., 65 equations.

Corner Losses in Ducts. G. N. Patterson. Factors affecting the design of efficient corners in ducts and leading to reduction of resistance. Both round corners and corners with vanes are considered. Effects of increase in radius ratio on resistance coefficient, of angle of deflection on corner loss, of variation of height in relation to diameter; and of gap-chord ratio on resistance coefficient are shown. Article published by permission of the British Air Ministry. Aircraft Engineering, August, 1937, pages 205–208, 7 illus., 2 tables, 2 equations.

Field of Supersonic Flow Around a Solid of Revolution. C. Ferrari. Linearization of the equation defining the potential function of velocity, according to von Kármán, permits a unique treatment of the field of flow at either subsonic or supersonic velocity. Field of velocity around a cone adrift in supersonic flow is determined and moments of the fluid-dynamic action on a lengthened solid of revolution adrift in subsonic flow are calculated. An approximate method is explained which determines the "best ogive" and takes into account the sudden compression formed at the apex in in front. L'Aerotecnica, June, 1937, pages 507–518, 3 illus., 30 equations.

Gaseous Supersonic Flow Around a Body Having Dihedral Faces. L. Crocco. When a body having a cutting edge in the front is displaced at supersonic velocity in a gaseous medium, an impact wave is formed in front of the body which adheres to the cutting edge after a certain velocity has been attained. The phenomenon is analyzed in order to account for the turbulence after impact and the critical Mach number is discussed. L'Aerotecnica, June, 1937, pages 519–534, 2 illus., 38 equations.

Research Work Accomplished by Wladimir Margoulis. A. Toussaint. A wind tunnel designed for Japan for testing wing models (speed 600 meters / second, diameter 1 meter, and 1200 hp.) and an unique wind tunnel for testing propellers at speeds up to 200 meters/second in rarefied air are referred to briefly in a review of the work of Margoulis in the field of aerodynamics, helicopters, propellers, and high-speed wind tunnels. Research on recuperation of kinetic energy in the wind tunnel, and a new supercharger comprising groups of two rotors turning in opposite directions are also mentioned. L'Aéronautique, Supplement, May, 1937, pages 122–125.

Some Ideas of von Kármán on Progress in Aerodynamics. Laminar flow, low aspect ratio of wings, high-lift ailerons, wings with straight leading edge, Fowler flaps, study of motions of the airplane, double fins to prevent spinning, liquid-cooled engines for high-altitude airplanes, three-wheel landing gear, small fuselages, pitch of rivets, and effect of blowing air through the trailing edge of the wing. Review of paper before Cercle d'Etudes Aerotechniques. Les Ailes, June 24, 1937, page 7, 5 illus.

Emergency Exits. So far as possible emergency exits are being provided in new types of aircraft for exit by parachute in the air, for exit on the ground from an overturned machine, and for exit on the ground from a multi-engined machine which has landed with undercarriage retracted. Few details of Air Ministry orders. Aeroplane, August 11, 1937, page 162.

Engines in the Trailing Edge of the Wing. W. K. Straford. In describing research results shown at the N.A.C.A. Langley Field conference, the author concludes with the statement that the up-to-date combat airplane of the Army Air Corps will have engines mounted on the trailing edge of the wing driving pusher propellers, will be armed with six machine guns, two in front, two in the wings and two in the rear, and will have a pressure cabin for operation at 10,000 meters. Les Ailes, July 29, 1937, page 8.

Fairey Flaps and the Law. Extension of the Fairey patent for split flaps for airplanes was refused on the ground that there had been no attempt to apply the invention to a commercial use during the whole life of the patent, and that it was therefore not an invention which had merit from the point of view of the public. Reasons why the flap was not used on earlier types of airplanes are given and its value for present designs is discussed. Aeroplane, August 4, 1937, page 127.

Flutter Research in Switzerland. H. L. Studer. Flutter occurring at high or negative incidences; additions to anti-flutter design rules resulting from wind-tunnel tests of models of different wing sections; danger points in "stall flutter" small reaction-vibrations of the fuselage causing disablement of the pilot when violent flutter occurs; and results of Reiher and Meister's experiments on human sensitivity to vibrations, showing that accelerations to which a pilot may be exposed when a wing flutters can have dangerous effects on him. Abstract from report of the Institut fuer Aerodynamik, Zurich. Aeroplane, July 21, 1937, page 79.

The Problem of Vibration of Aircraft. General G. A. A. Fiore. Observation of vibration in aircraft and its theoretical prediction, measures for preventing or reducing vibration, and behavior of materials and structures in the presence of vibration. The author reviews the work of research organizations of other countries and refers to results obtained in tests of rigid and torsionally-deformable wings at Guidonia. He discusses spring suspension of engines and vibration of tail surfaces and describes methods of testing aircraft structures. Tail surfaces and ailerons of the Ghibli airplane are illustrated. L'Aerotecnica, March, 1937, pages 187–216, 35 illus., many equations.

Studies and Tests of Airplane Skis. Method of connecting skis to the airplane, two types of skis used on the Hanriot 431, Potez 25 and Morane Saulnier 230 and 235, combined wheel and skis, details of the designs used on the two Morane Saulnier airplanes, and test results with these airplanes. Report of the Société Morane-Saulnier, Bureau of Research. Rev. de l'Armée de l'Air, June, 1937, pages 647–666, 24 illus.

This Flutter Business. A. G. Pugsley. Control surface and wing stability problems. "Either designers must plod on heavily up the stiffness gradient, or, to save the extra weight involved, they must find some practical means of cutting across the wing-flutter boundary, and even pass through the aileron-reversal and wing-divergence line." The author thinks the best method is to render wing flutter negligible by mass-balancing the wing itself which might be done either by adding weight in the leading edge or merely rearranging the wing motors or wing structure. Short abstract, Royal Aeronautical Society paper. Aeroplane, July 14, 1937, page 52.

Stress Analysis and Structures

Calculation of Box Girders. L. Kirste. Quick method is developed for locating the center of torsion of box girders and another center called the "center of bending" although it does not determine the condition of pure bending. L'Aeronautique, Supplement, May, 1937, pages 57–58, 1 ill., many equations.

Functions for Solution of Three-Moment Equation for Beam Columns with Nonuniform Loads. J. E. Younger. Errors introduced by the substitution of an elementary concentrated load for a distributed load when the element used is one tenth the length of the span. Discussion by H. M. Hansen of paper previously published. A.S.M.E. Trans., May, 1937, pages 352–353, 2 tables, 7 equations.

A New Wing. Wing designed primarily for construction in plastic materials has been tested and released at Farnborough with flying colors. The prototype wing was built in wood. The test was concluded when the wing-root fitting failed under a load of 12.3 times the weight of the machine (c.p. forward). The wing weighs only 1 ½ lb. /sq. ft. and has four continuous spars, the outer pair of which takes the place of normal front and rear spars. Where necessary these spars are linked together with simple diaphragms, but not ribs. The wing was designed by S. C. Hart-Still. It is intended for a two-seater airplane driven by a Cirrus Minor 85-hp. engine and having a wing loading of 8 ½ lb./sq. ft., aspect ratio of 7, and speed of 125 m.p.h. Three spars will be used in the plastic wing and will be of a bulbous, or rail-like section. Cores of the flanges will be lengths of metal tubing telescoping one into another. Long description of both types. Aeroplane, July 21, 1937, pages 75–76, 9 illus.

Plastic Materials for Aircraft Construction. N. A. de Bruyne. Aerolite applications to monoplane wing-root joints, shear bracing, cowlings, aircraft structures, bearings, spinning pots, and propellers are discussed in the last part of the article, and formulas are given for a flat plate in compression, compression of a cylinder without longitudinal stiffeners, rectangular strut of given width, and beam of given depth. First part of the article considers the properties of plastic materials and covers the following points: chemical constitution of Bakelite; its manufacture; physical structure; and behavior under small and large compressive stresses; and under tension, and compressive failure; properties of Bakelite with filler; tension reinforcement; properties of cord aerolite in compression and in tension; microphotographs; aerolite and Bakelite beams; effect of notches on tensile strength; general elastic properties and energy-absorbing properties of aerolite; effect of energy absorption on torsional shock and wing flutter; creep of aerolite; static, dynamic and impact fatigue of aerolite; its resistance to corrosion; water absorption; weathering test results; resistance to sea water; effect of oil and gasoline; heat and fire resistance; and glued and bolted joints. The author is Director of Aero Research, Ltd. which is engaged in research on plastic materials for aircraft. Jour. Royal Aeronautical Soc. July, 1937, pages 523–577 and (disc.) 577–590, 35 illus., 14 tables, 29 equations.

The Solution of Buckling Problems by an Approximate Method. A. N. Proctor. Solution for the problem of increasing the stability of a laterally unsupported beam by attaching a wide plate to one of the flanges. Concluded. Engineering, August 13, 1937, pages 184–185, 5 illus., 4 equations.

Why Not Timber? Due to the shortage of metal in England, it is suggested that wooden wings should be built for a number of types of airplanes in which all-metal wings, or metal covered with fabric, are part of the original design. Success of this construction in De Havilland and other airplanes is pointed out. Brief note. Aeroplane, July 21, 1937, page 67.

The National Physical Laboratory. Research on construction in thin sheet metal, especially the semi-monocoque type of light-alloy construction used for wings and bodies of all-metal aircraft, and examination of strength of electrically-welded joints are described. Other investigations undertaken by the Engineering Department on wheel impact of road vehicles, bridge stresses, eccentricity of bearings, driving belts, wind pressure and air flow, and the rectangular high-speed wind tunnel are also reviewed. Engineering, July 30, 1937, pages 129–131, 1 table.

The Solution of Buckling Problems by an Approximate Method. A. N. Proctor. Buckling of beams, beam with ends laterally fixed, combined bending and compression, ratio of lateral flange deflection, column braced on one flange, beam attached to filler beams on lower flange, beam with loads applied either at mid-depth, or above or below mid-depth, and correction for broad flanges. Continued. Engineering, July 30, 1937, pages 116–118, 12 illus., 20 equations.

Aircraft Performance

Calculation of the Speed Acquired by an Airplane in a Descent. Accelerated motion of the airplane on a vertical or inclined flight path is calculated by means of equations, and graphs are given for determining the velocity attained in gliding and in descent with full throttle. Report of the Director of Construction and Supply, Italian Air Ministry. L'Aerotecnica, March, 1937, pages 217–223, 4 illus., 6 tables, many equations.

Aircraft

America's Fast Trans-Atlantic Liner. Pan American Clipper III, the Sikorsky S.42-B, is described in detail and compared with the Short Caledonia. Aeroplane, July 14, 1937, pages 43–44, 3 illus.

International Aircraft Show at Brussels. Belgian, French, British, Dutch, Czechoslovakian, and German exhibits reviewed. Luftwissen, June, 1937, pages 188–190, 1 illus.

Munaret Rotary Wing. A four-bladed gyroplane designed by C. Munaret twelve years before Hafner used the same system for controlling incidence. The Munaret gyroplane is described and its polar diagrams are compared with those of the Cierva and Chauvière autogiros. In the second issue three Hafner inventions are described by the manufacturer and the Hafner and Munaret gyroplanes are compared. Les Ailes, April 29, and June 17, 1937, pages 6 and 7, 7 illus.

BELGIUM

The Renard R-35 Stratosphere Airplane. Airplane having a sealed cabin and powered by two Gnôme Rhône K-14 950-hp. engines will transport 20 passengers at a maximum speed of 435 km./hr. at 5000 meters and at a cruising speed of 350 km./hr. will have a range of 1800 km. The prototype will start test flights the end of September. The airplane will later be adapted for flying at higher altitudes. Short description of airplane and reference to special equipment necessitated by the stratospheric cabin. On the same page the Régnier 12 light sport airplane is described in detail by A. Frachet. Les Ailes, June 10, 1937, page 6, 2 illus.

FRANCE

Airplanes in Test. First issue—Hanriot 220 two-engined three-seater pursuit. Second issue—Bloch 131, Bréguet 462 bomber attaining a speed of 400 km./hr., Morane Saulnier 350 small single-seater training biplane powered with either a Renault 6-Pei 220-hp. or Salmson 6-Tes. engine, and the Renault 570 bimotored troop transport. Third issue—Potez 56 E.T.-3 bimotored (350-hp.) plane for operation from aircraft carriers, and the Caudron-Renault 570 (two Renault 18-Jbr 18-cylinder W engines) designed for transport of troops or of heavy or bulky loads. Brief notes on these military airplanes in test as well as references to commercial and sport planes being tested. Les Ailes, June 10 and 24, and July 15, 1937, pages 11, 13, and 10

New Airplanes in Test. First issue—Loire 250 (980-hp. Hispano Suiza 14-Ha engine), Bleriot-Spad 710, Caudron Renault C-690 pursuit trainer (new 6-cylinder 220-hp. engine, maximum speed 370 km./hr. at 2000 meters), and the Caudron Renault C-670 reprisal and reconnaissance airplane (two groups of 6-cylinder 220-hp. engines). Second issue—Latécoère 298 torpedo seaplane (Hispano-Suiza 880-hp. engine, speed around 290 km./hr. at 2000 meters, normal range 800 km., speed attained in dive 430 km./hr.), Bloch 150 pursuit airplane, and LeO-45 bomber (two Hispano-Suiza engines giving total of 2200 hp.). Brief notes on these new military aircraft in test as well as references to commercial and sport planes being tested. Les Ailes, May 6 and June 17, 1937, pages 11 and 5.

Consideration of the Weight of Wings. Prize-winning airplane with a single-spar wing which was designed by Alliet and Larivière for the Duralumin Competition. Drawing and brief discussion of weight of this type of Wing. Les Ailes, June 24, 1937, page 6, 1 illus.

The Dewoitine 338 Air Liner. New all-metal transport is capable of carrying 24 passengers and crew of four as well as freight and mail, is powered by three Hispano-Suiza 9 Vd 575-hp. engines, and has a maximum speed of 187 m.p.h. with a useful load of 11,771 lb. Few details. Engineering, July 30, 1937, page 133, 2 illus.

Records of the Kellner-Béchereau. Record speed flights made by Duverne over 100, 500, and 1000 km. in a Kellner-Béchereau monoplane having a sliding wing and powered by a Train 40-hp. engine. Les Ailes, June 17, 1937, page 14.

Technical Notes. First issue—LeO-49 seaplane with long range is being designed by S.N.C.A. to carry 5000 kg. or 40 passengers and 2000 kg. of freight over the South Atlantic at 300 km./hr. cruising speed. Second issue—Satisfactory aerodynamic qualities of the gun turret below the fuselage of the Bloch 131 is referred to, and the necessity for reconsidering entirely the effect of high speeds on the armament of modern airplanes is discussed. Brief notes. Les Ailes, June 10 and 17, 1937, pages 7 and 6.

Villacoublay, 1937. Morane 405 (Hispano 860-hp. engine), Caudron 710 (Renault 650-hp. engine), and the Potez 63 "fighter-commander" monoplane (two Hispano 650-hp. engines). Comments on these and other airplanes shown at the "Fete de l'Air", and an account of the events . Aeroplane, July 28, 1937, pages 101–102.

Air-Couzinet 10 Bimotored Airplane. M. Victor. Low-wing monoplane weighing 8400 kg. in flight with 5800 liters of gasoline covers 7000 km. at 350 km./hour cruising speed. It is powered with two Hispano-Suiza 9 V-16 660-hp. engines. Few details Les Ailes, July 29, 1937, page 8.

Airplanes in Test. Hanriot 230 for training in piloting two-engined high-speed military aircraft (two 170-hp. Salmson inline engines); Hanriot 220 three seater (two Gnôme-Rhône 14-Mars 650/700-hp. engines); Loire 46 pursuit; and Breguet 462 Vultur bomber (two Gnôme-Rhône 14-No. 950-hp. engines). Brief notes on tests of these military planes, and of the Farman 2230 four-engined and Amiot 370 record airplanes. Reference also to the fact that the S.N.C.A. is constructing the N-561 single-seater pursuit and the L.N.-20 three-seater combat plane (two Gnôme -Rhône 14-Mars engines). Les Ailes, July 29, 1937, page 7.

GERMANY

B.F.W. Taifun Large Touring Airplane. A. Frachet. Messerschmitt M-108 four-place all-metal monoplane has a maximum speed of 300 km./hour and is powdered by an Argus As 10-C 240-hp. engine. Construction, characteristics and performance. Les Ailes, July 29, 1937, page 9, 3 illus., 2 tables.

The Hallore. New 5-passenger light transport equipped with two Hirth 240-hp. engines and having a cruising speed of 325 km./hr. at 2500 meters with a fuel consumption of 35 liters for 100 km. Photograph only. Les Ailes, July 15, 1937, page 9, 1 illus.

Hamburg Ha-139 Transatlantic Seaplane. A. Frachet. Twin-float four-engined seaplane for the North Atlantic service of the Lufthansa is designed for catapult launching from ships. Powered by four Junkers. Jumo 205-C 600-hp. engines, the seaplane has a top speed of 300 km./hr. and a range of 5500 km. at 250 km./hr. Long description of construction, characteristics, and performance. Les Ailes, July 8, 1937, page 8, 2 illus., 2 tables.

Helicopter Climbs to 2500 Meters. In a Focke-Wulf F. W.-61 helicopter, Rohls recently made a record-breaking flight for helicopters by climbing to 2500 meters, flying for 1 hr. 20 min., covering 16.4 km. in a straight line and 80.6 km. in a closed circuit, and attaining an average speed of 122.5 km. over 20 km. Few details of the helicopter and comparison of these records with those made with the Bréguet-Dorand gyroplane and the Ascanio helicopter. Brief note. In the second issue O. DeAsboth, designer of another type of helico ter, discusses the question of whether the Focke Wulf F.W.-61 should really be considered as a helicopter. Les Ailes, July 8 and 15, 1937, pages 4 and 7–8.

Germany's New Fighter. Henschel twin-motored fighter is thought to be powered by the new Junkers Jumo-210 12-cylinder inverted gasoline engines designed to take cannons firing through the propeller hubs and giving presumably a total horsepower of 1600 or so. Few speculations from the photographs regarding probable armament and the comment "We have not heard whether it has been for a holiday in the South, where all good airplanes should be tested." Aeroplane, August 11, 1937, page 172, 2 illus.

The Record Breaker. New Focke-Wulf F.W.-61 helicopter which recently established new records for height (8200 ft.), distance (50 miles), speed over 20 km. (12.4 miles) 76 m.p.h., and duration (1 hr. 20 min. 50 sec.). The only supporting surfaces are the two three-bladed counter-revolving rotors driven through shafts by the 160-hp. Bramo Sh14A motor. When the motor is stopped the rotors operate like autogiros. Photograph only. Aeroplane, July 21, 1937, page 66.

Photographs of the helicopter in flight and on the ground, and records approved by the F.A.I. Les Ailes, July 29, 1937, pages 1, 3, 3 illus.

Technical Notes. The Junkers 90 40-passenger airplane is powered with new Daimler-Benz liquid-cooled heavy-oil engines. Two new prototypes designed for European lines have four Junkers heavy-oil engines. One is a 35-place airplane and the other a 24-place. They will fly at more than 300 km./hr. Brief references. Les Ailes, July 29, 1937, page 9.

War Material in Spain. ". . . during an air battle one Heinkel, one Fiat chaser and a new Dornier bomber of the Nationalist Air Force were shot down. According to information handed to him (the newspaper correspondent) by the Red Press Bureau, one of the German prisoners who escaped by parachute said that he belonged to a group of aviators who were testing ten Dornier bombers, under war conditions, and that they had come to Spain under military orders. They claim this is the best German bomber yet produced . . . The trimotor Junkers bombers (the Ju.52) are slow and provide an easy mark for anti-aircraft guns, and are being replaced by the twin-motor model (the Ju.86), which has Diesel motors. . . We hear that the Jumo Diesels, although they give a lot of power, are still not so reliable as the other motors." Brief notes from a newspaper correspondent and reference to the new type of German fighter which appeared recently, thought to be the Henschel and having terrific climb and being particularly good as a dive bomber. Aeroplane, August 4, 1937, page 128.

Henschel Hs-125 Training Airplane. A. Frachet. Single-seater designed for training pilots of pursuit airplanes is equipped with an Argus As 10-C 200/240-hp. engine and has a maximum speed of 280 km./hr. and range of 500 km. Long description of construction, characteristics, and performance. Les Ailes, May 6, 1937, page 6, 2 illus., 2 tables.

Other Nations at Zurich. T. James. *B.F.W*, BF-109 single-seater fighter (950-hp. Daimler-Benz 600 engine or 640-hp. Junkers Jumo 210 engine, reported top speed about 540 km./hr., landing speed 90 km./hr). *Daimler-Benz* 600 liquid-cooled engine. *Heinkel* single-seater (650-hp. Junkers Jumo 210 engine). *Dornier* Do 17 high-speed bomber (two Daimler-Benz engines, reported top speed 270 m.p.h., 2000 lb. bombs, range 1500 miles). *Henschel* HS 123 dive bomber (800-hp. B.M.W.-built Hornet engine). New slotted and flapped Fieseler (240-hp. Argus engine). Few details of these airplanes exhibited at the International Flying Meeting and some of the competitions. Aeroplane, July 28, 1937, pages 98–100, 97, 11 illus.

Technical Notes. The new Junkers will have a total weight of 20 tons with 40 passengers and cruising speed between 350 and 400 km./hr. Flight, will start at the end of the year. Brief reference. Les Ailes, June 10, 1937, page 7.

GREAT BRITAIN

The Airspeed-Oxford. Airspeed A.S. 10-Oxford twin-motored trainer to be built in mass production for the British Air Ministry is designed for training in bombing, air gunnery, radio operation, navigation, and aerial photography. Powered by two 375-hp. moderately supercharged Armstrong-Siddeley Cheetah X engines, the airplane has a top speed of about 196 m.p.h. at 7500 ft. Duration is 5¾ hours at 161 m.p.h. cruising speed with standard tanks for 156 gallons. Modification of equipment turns the Oxford into a useful general purpose type. De-icers are the only things the machine seems to lack and presumably the Air Ministry has not yet made up its mind on a standard type. Very long description of construction, armament, equipment, and performance, and cutaway drawing showing location of equipment. Windscreen is compared with those seen on several new American types. Aeroplane, July 28, 1937, pages 111–114, 8 illus.

Climb to 16,440 Meters by Lieutenant Adam. Account of record-breaking flight and references to the Bristol 138 airplane, Bristol Pegasus P.E. VI S engine with two superchargers, and the four-bladed propeller. Les Ailes, July 8, 1937, page 11, 1 illus.

The Independent British Industry Takes the Leader's Place in the World Competition. Six new Hawker Fury multi-gun pursuits being built for the Yugoslavian air force, the Napier Dagger 24-cylinder engine developing 860 hp. at 4000 r.p.m., the DeHavilland Albatross transatlantic airplane, and the Bristol Hele-Shaw propeller are discussed and drawings of the propeller are given. Les Ailes, June 17, 1937, page 8, 3 illus.

This Record Business. Possibility that the Vickers Wellesley or Vickers Wellington might be able to regain for Great Britain the long-distance flight record recently won by the Russian airplane. Brief note on range, load, and speed of the Wellesley, and a suitable route for such a flight. Aeroplane, July 28, 1937, page 96.

The Armstrong Whitworth. The A.W. 38 Whitley I is driven by two 880-hp. moderately supercharged Armstrong-Siddeley Tiger IX engines which give it a speed of 192 m.p.h. at 7000 ft. Later editions, the Mark II and Mark III Whitley will have two 920-hp. Tiger VIII engines which will put the top speed up to 215 m.p.h. at 15,000 ft. With gunners in the nose and tail, and another below and behind the wing, there can be very few blind spots for attack. Construction, methods of production, internal arrangement, and flying qualities are described in detail with many drawings, and specifications and performance are given. Aeroplane, August 11, 1937, pages 168–172, 155, 17 illus.

Building the Handley Page Harrow. Structure of the bomber is described in detail with many drawings, and methods of production are discussed. Powered now with two Bristol Pegasus XX engines (925 hp. maximum at 10,000 ft.) the bombers are credited with a maximum speed of 200 m.p.h. Characteristics and performance. Aeroplane, August 4, 1937, pages 138–142, 26 illus.

Exercises in Design. T.K.4 small monoplane designed by the DeHavilland Aeronautical Technical School students should do well over 200 m.p.h. on 137 hp. Few details and flight performance. Aeroplane, August 11, 1937, page 181, 5 illus.

The First Commercial Crossing. Caledonia, first of the two Short Empire flying boats (four 940-hp. Bristol Pegasus Xc engines) to cross the Atlantic on experimental flights. Special radio equipment comprising four sets, speeds and fuel consumption are discussed and a diagram given of the fuel arrangements in the flying boat. Aeroplane, July 7, 1937, page 4.

Flying at the S.B.A.C. Show. F. D. Bradbrooke. Comments on the performance of the following: DeHavilland Albatross; Hawker Henley light bomber; Handley-Page Harrow heavy bomber and Hampden medium bomber; Bristol Blenheim bomber; the Bristol Perseus engine and Bristol Rotol controllable-pitch propeller in Hawker Harts; the Vickers Wellesley and Venom; C.W.A. Cygnet; new Miles 290-m.p.h. R.R. trainer and Magister; the Whitney Straight Special; Fairey P4/34; Calpurnia Empire flying boat; Heston Phoenix; Blackburn Shark; Percival Mews and Vega Gulls; Armstrong Whitworth Whitley bomber; Gloster monoplane fighter and the Gladiator; Westland Lysander; Aeronca; Supermarine Walrus; and Hafner gyroplane. Aeroplane, July 7, 1937, pages 16–19, 7 illus.

Photographs Only. Gloster F.5/34 monoplane fighter (840-hp. Mercury IX engine). Aeroplane, July 7, 1937, page 13, 1 illus. New Gloster P4/35 single-seat fighter (840-hp. Bristol Mercury engine). Aeroplane, July 21, 1937, page 69, 1 illus. Maia, lower component of the Mayo composite aircraft from the back of which a four-motored monoplane on floats is to be launched as a trans-Atlantic high-speed mailplane. The Maia is like the regular Empire boats, but tapers from the bottom to the top, and the tail is swept upwards. Aeroplane, August 4, 1937, page 126, 1 illus.

"The Miles-Rolls-Royce trainer (725-hp. Kestrel) with Lockheed undercarriage and Perspex roof. An example of the Return to Timber policy." Aeroplane, August 4, 1937, page 127, 1 illus.

Vickers Wellesleys (Pegasus motors). Aeroplane, August 4, 1937, page 132, 1 illus.

HOLLAND

Koolhoven F.K.52 Two-Seater Combat Airplane. Powered with the Bristol Mercury 830-hp. engine, the airplane has a maximum speed of 370 km./hr. at 4400 meters. Characteristics, performance, and armament in a brief note. Reference is made to the Koolhoven F.K.46 two-seater for training in acrobatics. Rev. de l'Armée de l'Air, June, 1937, pages 712–713, 2 illus.

The Netherlands Aero-Show. C. G. Grey. An account of the Show and references to the British, Dutch, and German aircraft and engine exhibits. Aeroplane, August 11, 1937, pages 157–160, 10 illus.

ITALY

Gone Abroad to Take the Orders. Twelve Savoia Marchetti 79 high-speed bombers powered by two Gnôme Rhône K-14 engines have recently been ordered by the Rumanian government. The Chilean government has decided to buy 1,000,000 pesos worth of military equipment from Italy and Germany. Brief reference. Aeroplane, August 11, 1937, page 167.

New Italian Records. A three-motored Savoia Marchetti S 79 (Piaggio engines) carried a commercial load of 4400 lb. over 621 miles at an average speed of 264.76 m.p.h. and also set up new records for loads of 1100 lb. and and 2200 lb. Brief reference. Aeroplane, July 21, 1937, page 69.

The Savoia Marchetti S.84—2200 hp. Bimotored Savoia-Marchetti S.84 18-passenger transport has a maximum speed of 341 km./hr. at 1400 meters and range of 1650 km. at a cruising speed of 316 km./hr. Two engines (name not mentioned) will give a total power of 2200 hp. at 1300 meters. Construction, characteristics and performance. L'Aerotecnica, June, 1937, pages 561–562, 7 illus., 1 table.

Bergamaschi Ghibli Colonial Airplane. A. Frachet. Light Italian bimotored airplane developed from the Boréa transport and designed for patrol and observation in Italian territories in Africa. It covers 1500 km. at a speed of 220 km./hr. with military equipment consisting of aerial cameras, bombs and machine guns. It is powered by two Alfa Romeo A-115 6-cylinder inline inverted 200-hp. engines and has a top speed of 255 km./hr. Construction, characteristics and performance. Reference is made to the Libeccio airplane designed for training pilots for modern two-engined airplanes. This airplane has a top speed of 335 km./hr. at 1500 meters and is powered by engines giving a total of 750 hp. Les Ailes, June 24, 1937, page 6, 2 illus., 2 tables.

Fiat G-50 Single-Seater Pursuit. A. Frachet. Metal airplane said to be powerfully armed and to have good visibility. The airplane is equipped with a Fiat A-74 RG-38 14-cylinder radial two-row air-cooled engine developing 850-hp. at 3800 meters and driving a three-bladed automatic variable-pitch propeller. It has a maximum speed of 460 km./hr. at 4000 meters, cruising speed of 420 km./hr., and a range of 680 km., and climbs to 5000 meters in 6 minutes. Long description of construction, characteristics and performance. Les Ailes, July 15, 1937, page 8, 2 illus., 2 tables.

For the South Atlantic. Cant Z-506 three-engined seaplane with which speed records were made over 5000 km. with 500- and 1000-kg. load at an average speed of 308 km./hr. Photograph only. Les Ailes, June 24, 1937, page 11, 1 illus.

JAPAN

Japanese monoplane developed at the Aeronautics Institute of the Imperial University has a wing span of 28 m. and is designed to carry 7000 liters of fuel, to remain in the air for 80 hours, and to cover between 13,000 and 16,000 km. at an average speed of 200 km./hr. Few details and photographs of airplane being assembled in the shop. Les Ailes, May 6, 1937, page 11, 4 illus.

U. S. A.

Bellanca Mailplane. Model 28-90, commercial version of the Mollison airplane, is powered by a Pratt and Whitney Twin Wasp providing 900 hp. at 6200 ft. and has a maximum speed of 280 m.p.h., cruising speed of 250 m.p.h., and range of 800 miles. Twenty of these planes have been purchased by Air France for high-speed mail service. Few details, specifications and performance. Aviation, August, 1937, page 46, 2 illus.

Clipper Wings Grow Larger. C. F. McReynolds, Jr. "Whatever may be the military value of the Boeing YB-17 and XB-15, their contribution to the construction and operation of large commercial planes cannot be exaggerated." References to flights of the YB-17 bomber at an average speed of 235 m.p.h., and details of the Boeing Model 307 landplane and Model 314 flying boats being built for TWA and Pan American Airways. Results of a study of large flying boats, made by Consolidated, the Douglas DC-4 airplane and DF flying boat, Martin Model 156 and proposed 150-passenger flying boat, and a new Sikorsky 40-passenger plane under way are discussed. A comparative table of representative landplanes and flying boats is included. Aviation, August, 1937, pages 38–39, 42, 45, 4 illus., 2 tables.

First Lockheed 14 Completed. Said to be the world's newest and fastest air-transport plane, the Lockheed 14 has a top speed of 265 m.p.h. at 8700 ft. Construction, use of Fowler flaps, characteristics, and performance. Western Flying, August, 1937, page 36.

Light American Sport Planes. H. Mignet. Comments by the designer of the Pou-du-Ciel. Les Ailes, June 10, 1937, page 8.

Midget Racer. New midget racer built by employees of Consolidated Aircraft Corporation. The plane is powered by a Pobjoy Niagara 90-hp. engine and has a maximum speed of 200 m.p.h. Specifications given. Aviation, August, 1937, page 45.

American Aviation. R. Boname; M. Jan-Kerguistel and M. R. Servel. Technical trends in American Aviation as observed by three Frenchmen on a visit to the United States, including: aeronautical firms and the Naval Aircraft Factory, their methods of construction and products; new technical tendencies in regard to welding, riveting, protection of metal, and plants; comparison of the Martin 130 China Clipper and Sikorsky S.42; and prices of the Douglas D.G.2 and Lockheed Electra and their equipment. Long, detailed report. To be continued. L'Aeronautique, May, 1937, pages 90–108 and 109–122, 60 illus., 6 tables, many equations.

New Pursuit Type Developed. Bell five-place twin-engined airplane developed for the U. S. Army Air Corps. Long description and references to engines driving pusher propellers, auxiliary power plant for operating equipment, and armament. Western Flying, August, 1937, pages, 34–35, 1 illus.

Payne Develops Monoplane. Model MC-7 two-place sport biplane powered by a Continental A40-4 engine driving a pusher propeller and having a top speed of 92 m.p.h. Few details. Western Flying, August, 1937, page 35, 1 illus.

Production Model "Y"—By Stearman-Hammond Has Many Detailed Refinements. Improvements incorporated in the 1937 Model Y, and specifications and performance of the Model Y-1 and Y-1S. Powered by a Menasco C4S supercharged 150-hp. engine the airplane has a maximum speed of 130 m.p.h. Brief. Aviation, August, 1937, page 49, 1 illus., 2 tables.

U. S. S. R.

Study and Realization of the Aerial Expedition to the Pole. Four four-engined Russian airplanes of 24 tons total weight landed 30 men and 10 tons of equipment near the North Pole. The A.N.T.-6 four-engined bomber, and the R.-6 bimotored reconnaissance and two light 100-hp. airplanes are stationed at Rudolph Island for various exploration and observation missions to the Pole. Technical difficulties and severe training described. Les Ailes, June 17, 1937, page 9, 1 illus.

With Foreign Builders. L. Zacharoff. Unusual features contributing to the record-breaking qualities of the Russian ANT-25 airplane which recently flew from U. S. S. R. to the United States over the North Pole. Construction and radio equipment of the airplane and development of its AN-34 liquid-cooled 12-cylinder 950-hp. engine are described. Comments by Professor Tupoleff on means taken to improve the flying range of the plane are included. Aviation, August, 1937, pages 50 and 53, 2 illus.

Airships

Airship Mooring in England. Capt. T. B. Williams. Systems of mooring in the air including the Usborne system and a single-wire mooring system. Brief. Continued. Airship, July–September, 1937, pages 22–23, 4 illus.

New Navy Airship Urged at Hearing. "We have plans now on the drawing boards of an airship of about 10,000,000 cu. ft. capacity which would carry nine bombing planes weighing with load about 10,000 lb. each." Remarks of Admiral Cook before the House Committee on Naval Affairs urging the building of a new airship to take the place of the Los Angeles. Brief note. U. S. Air Services, August,1937, page 35.

Practice in the Art of Balance. G. Brewer. Possibility of an airship descending on the water outside a harbor to take on water ballast and then proceeding under itso wn power into the harbor to pick up moorings. Feasibility is considered in the light of experience with temporary landings in spherical balloons 30 years ago, and difficulties in providing flotation gear for the Los Angeles are discussed. U. S. Air Services, August, 1937, pages 15 and 34.

Airship Program Advised for United States. Program recommended by the Air Commerce Planning Committee is reviewed. U. S. Naval Inst. Proc., August, 1937 pages 1202–1203.

Aircraft Accidents

The Accident at Hals. Major accident to a K.L.M. air liner near Brussels in which the airplane emerged from a cloud in flames and was thought to have been set on fire by lightning. References are made to instances in the United States of fire breaking out in the engine cowlings of air liners because of oil leaking from hydraulic systems of variable-pitch propellers, trickling back along the crankcase, heating up around the cylinders and then catching fire from the exhaust. Brief note quoting newspaper reports. Aeroplane, August 4, 1937, page 126.

Status of the Carrier. W. L. Robinson. United States, British, Japanese and French aircraft carriers. Description of present carriers, evolution of their design, installations, and carriers which are being built or planned. Scientific Am., August, 1937, pages 156–158, 4 illus., 1 table.

Aircraft Manually Driven

Note on the Possibility of Flight by Human Power. H. C. H. Townend. Facts suggesting that, from a purely aerodynamic point of view, the difficulties involved in flight by human power may not be as great as is generally supposed. Observations of Lippisch showing that the superiority of the flexible wing structure over the stiff-winged brace types is very striking, the Katzmayr effect reviewed by Cowley, information given by Kronfeld and Hill on power exerted by a man, and way in which the human body can most efficiently convert its energy into motion are discussed. Jour. Royal Aeronautical Soc., July, 1937, pages 609–611.

Air Transportation

Paris to New York Direct Without Landing Is the Aim of Air-France Transatlantique. P. Desbordes. Courses, powerful radio beacons needed, and the proposed aircraft of 53 tons cruising at more than 300 km./hr. are considered and reference is made to the Farman 2230 which is capable of making the distance without landing. Les Ailes, July 15, 1937, pages 3–4.

The Seaplane Catapult Ship Ostmark. Floating seaplane base developed for Deutsche Luft Hansa for its South American air-mail service. Long description. Engineering, July 23, 1937, pages 109–110, 100, 10 illus., 4 on supplement plates.

Traffic Control in the Clouds. F. D. Fagg. Need for Federal control of air traffic to prevent collisions between aircraft along civil airways, and suggestions made for regulations in regard to instrument flying are discussed by the director of the Bureau of Air Commerce. Western Flying, August, 1937 pages 13–14.

Double-Crossing the Atlantic. The Short Caledonia boat flew at an average speed of 133 m.p.h. and the Pan American Clipper at 157 m.p.h. Experiences of Pan American and Imperial Airways in flying across the Atlantic. Weights empty and loaded, fuel and oil carried, and range of the two boats are compared and reference made to the engines and equipment of the Caledonia. A second article discusses methods of navigation used on the trip. Aeroplane, July 14, 1937, pages 39–41, 3 illus.

The "Friesenland." Deutsche Lufthansa catapult ship to be used as a base in North Atlantic experiments. A few more details and photograph of the Ha-139 seaplane being hoisted aboard the ship. Aeroplane, July 14, 1937, page 53.

Propellers

A Constant-Speed Airscrew. New hydraulically-operated constant-speed controllable-pitch propeller made under Hele-Shaw-Beacham patents and to be manufactured by Rotol Airscrews, Ltd. Design and principle of operation. Engineer, August 6, 1937, page 164, 4 illus.

Plastic Progress. DeHavilland plastic propeller blades. A few details. Aeroplane, July 14, 1937, page 61, 3 illus.

The Vibration Problem in Aircraft Propeller Designing. F. W. Caldwell. Paper previously abstracted from preprint. See DIGEST, April 1, page 13. S.A.E. Jour. (Trans.) August, 1937, pages 372–380, 23 illus.

Helping the Seaplane Off. D. J. Brimm, Jr. Selection of the best propeller for water take-off in the smaller seaplanes not using the controllable-pitch propeller. Essential differences between take-off characteristics of the landplane and seaplane, the propeller needed for the latter, and results of comparative tests between propellers which were run on a Waco ZQC and a Fairchild 24 C8E. Aviation, August, 1937, pages 33–34, 2 illus., 2 tables.

Variable Pitch Propeller. Three-blade Rotol Hele-Shaw variable-pitch constant-speed propeller designed for the Pegasus 910-hp. engine. Long description. Les Ailes, July 8, 1937, page 10, 2 illus.

Records and Races

Flight of 712 Meters in a Manually Driven Plane. Flight made by Hoffmann, a German pilot; in a plane in which the propeller was manually driven, and details of the plane developed by Helmut, Haessler and Villinger. Les Ailes, July 15, 1937, page 12, 1 illus.

The International Records. Flight records approved by the Federation Aéronautique International for single-seaters of less than 450 kg. and multiplace airplanes of less than 280 kg., and various altitude records for seaplanes. Second issue—Altitude flight records for light seaplanes, amphibians and airplanes without motors. Third issue—Flight records of single seaters of less than 200 kg. and distance flight records for seaplanes, light seaplanes, and amphibians. Les Ailes, June 17 and 24 and July 15, 1937, pages 12, 13, and 15.

Records approved by the F.A.I. for aircraft up to April 1. Luftwissen, June, 1937, pages 191–193, many tables.

Maurice Rossi Covered 5000 Km. at 311 Km. per Hour. Record flight in the Caudron Renault "Louis Bleriot." Les Ailes, April 29, 1937, page 3, 1 illus.

More Mass Maneuvers. Distance and time flight records made by Consolidated PBY-1 class patrol boats in June and July. Brief note. Aviation, August, 1937, pages 64–65.

Slaves of the Wasserkuppe. Account of the International Gliding Competition July 4 to 18. Aeroplane, July 28, 1937, pages 104–106, 10 illus.

Soviet Aviation. Efforts of engineers and pilots of U. S. S. R. towards attaining records and references to some of the airplanes. Les Ailes, July 15, 1937, page 9, 1 illus.

The Twenty-Fifth Gordon Bennett Balloon Race. Account of the start of the Race and reference to the free ballooning taking place in Europe today. Airship, July–September, 1937, pages 26–27, 4 illus., 1 table.

Aircraft Instruments

Aircraft Operation Recorder. Friez "Flight Analyzer" comprising aneroid-barograph type recording altimeter and two electrically-operated time-operation recorders. Very few details. Instruments, July, 1937, page 173, 1 illus.

Manifold Gage. Kollsman 295–01 manifold pressure gage with the mechanism located in a vacuum sealed chamber or cartridge to eliminate any possibility of raw fuel or fumes entering the instrument from the intake manifold. Few details. Aviation, August, 1937, page 55, 1 illus.

Pitot Overcoats. Pioneer streamlined heating unit for pitot tubes. Few details. Aviation, August, 1937, page 54, 2 illus.

Standard Atmosphere and Sea-Level Pressures. L. P. Harrison. Sensitive altimeter of the Kollsman type, provisions for making adjustment for pressure variations, and meteorological sea-level pressure depending on pressure, temperature, and topography. Automotive Industries, August 14, 1937, page 229.

Alidade for Navigation. (L. Reymond). Alidades previously used, conditions to be fulfilled by a modern alidade, and an alidade with a collimator recently patented in France for ships but adaptable for air navigation. Rev. de l'Armée de l'Air, June, 1937, pages 714–718, 10 illus.

Installing Liquid Level Indicators. P. B. Shannon. Installation of the manometer used as a tank gage and operating conditions modifying pipe work connections. Instruments, August, 1937, pages 210–212, 16 illus.

Lovely to Look At. Smith chassis and flap indicators. Few details. Aeroplane, August 4, 1937, page 152.

Richard "Altiscope" Sight-Drift Indicator. The Altiscope comprises two lenses and a drift indicator capable of turning around a vertical axis by means of remote control. One lens gives a field of 38° for a magnification of 0.5, the other a field of 45° for magnification of 0.42. Rev. de l'Armée de l'Air, June, 1937, pages 709–712.

Technical Notes. Sphere of 8-cm. diameter utilized by the Institut de Mecanique des Fluides de Lille in testing airplanes. It is used to measure the speed vector in magnitude and direction in azimuth and to determine the side slip and incidences of the airplane on its flight path. Photograph only. Les Ailes, July 29, 1937, page 8, 1 illus.

Seeing Through Fog. Aldridge Detector can be mounted in the nose of an airplane to give visual or aural warning and direction of any obstruction in its path, even at a distance of 20 miles. Waves slightly longer than the infra-red are radiated from the obstruction through darkness, snow and fog, are picked up by the Detector, and are converted into visual or aural signals. Two special detector valves are permanently tuned to pick up the waves on the 1.6-micron wave length. Power is supplied by three high-tension and two low-tension batteries and the whole apparatus weighs 40 lb. complete. Its use will cause no interference to radio apparatus and the airplane need not be bonded for it. The instrument has been tried in airplanes with great success. It may also be used for homing on a suitable source of light, and for signalling. Aeroplane, July 21, 1937, pages 76–77, 1 illus.

Airport Equipment

Modern Refueling Equipment. Several hundreds of Zwicky bomber refueling units and nearly as many fighter refueling units have already been supplied to the British Air Ministry and orders are being filled for other countries. Long description of pump, truck and the Rellumit refueling unit. Aeroplane, July 21, 1937, pages 91–92, 3 illus.

Electrical Equipment

Present-Day and Probable Future Electrical Applications in Aircraft W. V. Boughton. Electrical installations in the Douglas sleeper transport are described in detail, including: current supply, circuits, instrument operation, lighting, radio, wiring, shielding, bonding, and weight of equipment. Design problems to be solved in designing electrical equipment for aircraft are considered in regard to weight, operating temperatures, operating noise, power supply, supply characteristics, and use of frequencies as high as 800 cycles to save weight of equipment. Electrical Engineering, August, 1937, pages 959–963, 5 illus., 4 tables.

Ice Elimination Equipment

Means of Preventing Ice Formation on Wings. A. Faure. Method of using viscous coatings, a chemical method, and an electrical deicer are considered. A second article describes results of tests on a French electrothermal deicer, and its installation on aircraft. Les Ailes, July 15, 1937, page 6–7, 5 illus.

Miscellaneous Equipment

Dusting Central America. F. Miller. Bimotored airplanes, carrying two tons of dust, are required to solve Central America's dusting problem. Airplanes used and equipment developed described. Western Flying, August, 1937, pages 15–18, 6 illus.

Light from Water. New Sea-Lite marine light is useful as an emergency device on life-preserver jackets and operates with no fuel other than sea water which, with two dissimilar metals, serves to produce an electric light. Brief reference. Aviation, August, 1937, page 54.

Rubber Valve. Jenkins rubber capless valve for tires is said to save tube rips after deflation. Brief reference. Aviation, August 1937, page 55, 1 illus.

Useful Ideas. Method of mounting fuel tanks used by C. W. Aircraft, and the Walker safety nut which is securely held from turning by the chamfered washer. Drawing only. Aeroplane, July 14, 1937, page 52, 3 illus.

Parachutes

Bringing Them Out Alive. S. Ireland. When a modern highly-streamlined airplane breaks as the result of enemy action, or accident, its speed may be so high that the consequently enormous air pressure may prevent the crew from making use of their parachutes. Even if they could get out, the sudden deceleration caused by the bad streamline shape of a falling man might cause death. Conditions are analyzed and suggestions are made in regard to decreasing the drag of man and parachute, greatly increasing his weight with some detachable load, or providing a suitable decelerating arrangement on the airplane such as a parachute or drogue. Table shows drag of man and parachute for air speeds of from 100 to 500 m.p.h. Aeroplane, July 14, 1937, pages 49–50, 2 illus., 1 table.

Life Saving. G. Q. Parachute Company's new Parasuit. Few details. Aeroplane, August 4, 1937, page 152.

Parachute Training in America by Means of Towers. Course of instruction given by the Safe Parachute Jump Company described in detail. Rev. de l'Armée de l'Air, June, 1937, pages 697–705, 8 illus.

An Automatic Supercharger Regulator. Two-position regulator developed by Eclipse Aviation Corporation automatically maintains maximum boost at take-off and also limits the boost under long cruising conditions. Short explanation. Scientific Am., August, 1937, page 1000, 1 illus.

A French Radiator for Low Speeds. Ferlay radiator the parts of which form the surface of the engine cowling. Each of the radiating surfaces is inclined in the current of air in such a way that they regulate the temperature. Few details of principle. Les Ailes, July 8, 1937, page 10, 2 illus.

A Greek Engineer Uses Vaporized Masut for His Engine. Beroudar apparatus which supplies for all types of engine a masmut gas obtained by cracking in a closed container. Results obtained with this fuel supplied to a Chevrolet engine. Brief. Les Ailes, July 8, 1937, page 10.

Improved Type of Injection Nozzle. Improved design in which the valve guide is not subjected to the pressure of the nozzle retaining means. Description of injection nozzle for Diesel engines recently patented in Germany by Gebr. L'Orange. Abstract from ATZ. Automotive Industries, August 7, 1937, page 201, 2 illus.

In the News. Claudel-Hobson Master Control carburetor used for the British height record and for the Caledonia's Atlantic crossing. Built into it are a three-stage Variable Datum Boost Control and a two-stage Automatic Mixture Control, which, with the proper interconnecting linkage, take out of the pilot's hands all responsibility for correct boost pressures in all flying conditions and also for correct mixture strength. Photograph only. Aeroplane, July 28, 1937, page 122, 1 illus.

Technical Note. Brandenburg system of carburation in which a carburetor supplied with gasoil furnishes a very rich mixture. Reference to tests on the Mengin 35-hp. air-craft engine. Les Ailes, May 6, 1937, pages 6–7.

Turbines

Technical Notes. New generator-turbine for aircraft has been developed by P. Pescara, helicopter designer. The cylinders have free pistons serving as generators of the gas. The useful power serves to compress the air for scavenging and supercharging which is carried out at 4 kg. pressure. Two groups of generators with a power equivalent to 600 hp. are joined to the turbine. The latter has six high-pressure stages, develops 1200-hp. at 10,000 r.p.m., and drives a propeller through reduction gear. The system appears to conserve power up to 10,000 meters and has an estimated weight of 800 gr./hp. Short description. Les Ailes, June 10, 1937, page 7.

Steam Power Plants

Technical Notes. Steam power plant for aircraft, said to have been developed by M. Broobeck in the United States, has a 1000-hp. turbine of 0.45-meter diameter, and weighs 0.1 kg./hp. Brief reference. Les Ailes, April 29, 1937, page 7.

Radio

An Analysis of the Flight of an Aeroplane, When Directed by Means of a Radio Beacon, for All Possible Values of Wind Velocity. F. B. Greatrex. Analysis showing also the increase in flying time over a compass course, as well as the maximum deviation from the compass course. A flight from England to America and back is used as an example. Jour. Royal Aeronautical Soc., July, 1937, pages 591–594, 7 illus., 2 tables, 8 equations.

Institute News and Radio Notes. Summaries of Pacific Coast Meeting papers to be presented in Spokane September 1 and 2. Very brief abstract of "Aircraft Radio Equipment Trends" by R. M. Heintz included.

Among other section-meeting papers reference is made to "Ultra-Short-Wave Radio Landing Beam for Aircraft," by E. Kramer of the Lorenz Radio Company, "Radio Equipment used by the Department of Commerce Aeronautics Division," F. C. Mashburn, "Radio Equipment Used by Modern Air Lines," H. L. Bannon, and "Improvement in Air Navigation Radio Facilities," W. E. Jackson. Proc. Inst. Radio Engrs., August, 1937, pages 923–929.

Advance Against Snow Static. D. G. Fink. United Air Lines program for gathering data for forecasting static conditions, for development of a working theory of static production, and for the design of antenna and devices intended to reduce the cause of static at the source. Brief review of results obtained. Aviation, August, 1937, pages 30–31, 2 illus.

Lightplane Radio. RCA AVR-10 and AVR-10-A aircraft radio receivers are designed for the small plane but may be used as an auxiliary receiver for other types of aircraft. Weight is 8.5 lb. Few details. Aviation, August, 1937, page 54, 2 illus.

Midget Radios for 'Planes. World's smallest radio receiver and transmitter for airplane use weighs only 1 1/2 lb. and is said to be as efficient as much larger sets. Photograph only of apparatus contained in the Waco flying laboratory of the RCA radio section. Business Week, August 7, 1937, page 35, 1 illus.

Radio and the Private Pilot. C. L. Moser. Main points to be considered in obtaining and installing radio for the private airplane, including bonding and shielding, radio antenna installation. power output. total weight, and cost. Western Flying, August, 1937, pages 10–12, 4 illus.

Radio Transmitter. Aerovoice D-30 aircraft radio transmitter weighing 17 3/4 lb. and containing four tubes, three of which are 6L6's. Few details. Aviation, August, 1937, page 54, 1 illus.

Snow Static. H. M. Hucke. United Air Lines research on static disrupting radio reception on aircraft is described in detail. Discussion covers: six variables affecting electric charge on aircraft; means for discharging the charges on the plane without causing radio interference; antenna tests; experimental wooden nose covered with copper foil and installed on the fuselage; and charging with respect to the plane of insulated surfaces such as windshields, deicers, and nonmetallic loop housings. Western Flying, August, 1937, pages 22–25, 26, 3 illus.

Technical Notes. Cougnot automatic transmitter of Morse signals such as "all is well," "forced landing," and "S.O.S." The transmitter consists essentially of an electric motor driving a gyroscope, the whole equipment being connected in a box fixed on the airplane and taking the form of the modifications of the trajectory when the motor and its gyroscope remain vertical. Few details. Les Ailes, July 8, 1937, page 8, 1 illus.

Meteorology

The Formation of Ice on Aircraft. H. Noth and W. Polte. Most dangerous kind of ice formation is supercooled rain. If an airplane encounters this condition, the pilot should immediately get away from this region, since to remain in it or to continue flight in it is highly dangerous. Processes and types of ice formation are described in detail. Special cases of ice formation, effect of ice formation on airships and airplane, and weather conditions for ice formation are discussed. Means for preventing ice accretion by means of horizontal and vertical navigation, and technical remedies are explained. Procedure in case of ice accretion is outlined. Air Ministry translation from Luftwissen, November, 1935. Jour. Royal Aeronautical Soc., July, 1937, pages 595–608, 9 illus.

Automatic Weather Observer. Robot weather observers to be sent aloft by the Weather Bureau in Alaska and California. Instruments to be used are described. U.S. Air Services, August, 1937, pages 30, 32.

Meteorological Instrument Assemblies for Airports. Friez "Airport Weatherman" receiving station for three or four remote-indicating and self-contained weather instruments. Few details. Instruments, July, 1937, page 178, 1 illus.

Sounding the Atmosphere at High Altitudes by Means of Sounding Balloons. E. Cambi. On the basis of the size coefficients which characterize the sounding equipment, an optimum value is defined in regard to inflation of the envelope. A formula is derived that in function of the coefficient, expresses these values and the corresponding maximum height attainable. L'Aerotecnica, March, 1937, pages 224–236, 2 illus., many equations.

Aeronautical Industry and Production

New Production High. Startling gains in production and export of American aeronautical products. Reference to Department of Commerce reports on increase in production and exports for the first quarter of 1937 compared with that in 1936. Aviation, August, 1937, pages 65–66.

Short Spans. Formation of the Aircraft Manufacturing Division of Bendix Aviation Corporation, and of the Bennett Aircraft Corporation, and factory expansion of Lockheed which has been planned. Western Flying, August, 1937, pages 32, 34–36.

Export Numbers, Without Values. Table showing number of complete airplanes of United Kingdom manufacture which were exported during the years ending March 1936 and March 1937. Brief. Aeroplane, July 14, 1937, page 36.

Workers and Passengers. An official statement from Rome states that there are more that 45,000 workers in the Italian aircraft factories. Brief reference. Aeroplane, July 14, 1937, page 36.

Pilots

"Aviator's Ear" Described in Medical Journal. Aero-otitis media, suffered by pilots and passengers in flight, is caused by pressure difference between the air in the tympanic cavity and that of the surrounding atmosphere. Brief abstract of article by Capt. Harry G. Armstrong and J. W. Heim in the Journal, American Medical Association. Science News Letter, August, 28, 1937, page 134.

The Case for One-Eyed A-License Pilots. By an Ophthalmic Surgeon. Proposed standards for one-eyed A-License pilots. Aeroplane, August 4, 1937, page 145, 1 table.

New Criterions and New Methods for the Psychotechnic Selection of Pilots. Padre Gemelli. Methods for selecting pilots. Long discussion from Rivista di Psicologia. L'Aerotecnica, June, 1937, pages 557–560.

Precautionary Measures to Be Taken for High Altitude Flight. Troubles encountered at high altitudes and precautions to be taken. Study for Belgian pilots published in the Bulletin Belge des Sciences Militaires, March. Rev. de l'Armée de l'Air, June, 1937, pages 705–706.

The Doctor, Engineer, and Leaders. Commandant A. Langeron. First issue—Collaboration of doctors, engineers, and military leaders is urged in investigating effects of speed and altitude of flight on pilots. Second issue—Advantages of operating military airplanes at altitudes between 6000 and 12,000 meters, and problems regarding the effect on pilots. Third issue—Further discussion of effects on pilots of flight at these altitudes with references to work of the U. S. Army Air Corps and German organizations. Fourth issue—Physiological phenomena caused by accelerations in flight. To be continued. Les Ailes, June 3 and 17, July 1 and 15, 1937, pages 13, 13, 11, and 11.

Ordeal by Air. Lt. B. Lay, Jr. Physical endurance required of pilots taking part in the recent maneuvers of the GHQ Air Force Units on the West Coast. U.S. Air Services, July, 1937, pages 13, 37, 2 illus.

Air Forces

First Come, First Served. Two Bristol Blenheims recently left Croydon for Finland and others have been sold to Turkey. Brief reference and suggestion that the R.A.F. lend a dozen to the Royal Canadian Air Force with which to run the experimental trans-Canada air mail. Aeroplane, August 11, 1937, page 173.

Another Convention. Aircraft carriers are limited to 23,000 tons displacement and their armament to guns of not more than 6-in. caliber, and Germany is allowed to build 35 percent of the English tonnage of aircraft carriers, as fixed in 1935. Brief reference to naval convention between England and Germany, and England and Russia signed July 17. Aeroplane, July 28, 1937, page 95.

GREAT BRITAIN

An American View of the Air Force Display at Hendon. J. Arre. Account of the Royal Air Force Display and an illustration of the new Blackburn dive-bomber fighter of the Fleet Air Arm. U.S. Air Services, August, 1937, pages 24, 26, 29, 1 illus.

The Navy and the Air. Combined maneuvers to explore possibilities of air reconnaissance and to test the working of the system of Navy and Air Force cooperation in coastal defense. Brief editorial account of the maneuvers, and discussion of the Prime Minister's announcement that all ship-borne aircraft are to come entirely under Admiralty control, but that shore-based aircraft, including flying boats, detailed for coastal reconnaissance are to remain under the Air Ministry. Questions of supply and training of pilots, and the impending growth of the Fleet Air Arm are also considered. When the naval rearmament program is completed the total of ship-borne aircraft in the Fleet Air Arm should approach 600 as compared with present-day strength of approximately 225. Engineer, August 6, 1937, page 155.

Materials

Specification-Mongers, Please Note! W. S. Shackleton. Multiplicity of British specifications for aeronautical material is criticized with special reference to steel tubing and cotton wing fabric. American specifications are praised. Aeroplane, August 4, 1937, page 143.

New Material Standards. E. Hain. German standards in regard to testing materials, iron and steel, and non-ferrous alloys. This is followed by articles on nickel-free alloyed construction steel in automobile engines, aircraft-engine materials (J. B. Johnson's paper), and light metals in automobile construction. A.T.Z., June 25, 1937, pages 297–299 and 299–311, many illus. and tables.

The "Index of Duration" of Flexible Control Cables. A. R. Tripodi. Wear tests of flexible control cables carried out on machines constructed for the Registro Italiano Navale ed Aeronautico. Details of the machine used, results of tests, and factors entering into an index of duration for flexible control cables. L'Aerotecnica, March, 1937, pages 237–245, 4 illus., 1 table, many equations.

Essential Accessories. Oil- and gasoline-resisting rubber joints and other parts made by Technical Rubber Company and standardized by the Bristol Aeroplane Company. Few details. Aeroplane July 14, 1937, page 60.

Textile Uses in AIRCRAFT. Present policy of the aircraft industry regarding textiles, textiles preferred for interiors, general types of textiles most used, fabrics for curtains, soundproofing with Seapak, and fabrics used in certain planes. Brief note. Textile World, August, 1937, page 1778, 1 illus.

Engine Design and Research

Alternating Stress Measurement by the Resistance Strip Method. E. H. Hull. Method of alternating-stress measurement useful for determining stresses in rotating and nonrotating parts. Preparation of the strip, characteristics and calibration of strips, and equipment used. General Electric Rev., August, 1937, pages 379–380, 2 illus.

Aluminum-Alloy Heads Tested. Aluminum head with 5.95 compression ratio gave an increase of 2 per cent in maximum power. Advantages of aluminum-alloy cylinder heads from the standpoint of engine output and fuel economy were investigated. Test results obtained with a Citroen automobile engine by the Bellevue National Research and Experimental Laboratory, French National Liquid Fuels Department, Abstract from Revue de l'Aluminum. Automotive Industries, August 14, 1937, pages 232-233.

Diesel-Engine Research. Injection control in high-speed Diesel engines, mixing process, special considerations for high-altitude and long-distance flights, increase of power obtained by supercharging, high pressure for starting, and measuring apparatus for high-speed engines. Very brief review of papers presented by DVL and Dresden University men before the Lilienthal Gesellschaft fuer Luftfahrtforschung at Dresden University in May. Luftwissen, June, 1937, pages 167–168.

Supercharging for Small Displacement. With a boost of 13½ in. of mercury column, output of an engine can be doubled while fuel consumption remains the same. Conclusions so far reached in an investigation of the fundamentals of supercharging being undertaken by the research department of the Ethyl Gasoline Corporation. Brief note. Automotive Industries, August 14, 1937, page 232.

Errata. Correction to article entitled "Correction for Power in Supercharged Engines" which appeared in the September, 1936 issue. A new formula and new graph are given to replace figure 9. L'Aéronautique, Supplement, May, 1937, page 60, 1 illus., 4 equations.

Factors Influencing Aircraft-Engine Development in France. Abstract of paper entitled "Design Trends in French Aircraft Engines and Propellers," by H. L. Brownback. (See DIGEST, April 1, page 34, for abstract of preprint.) S.A.E., July, 1937, page 18.

Lubrication and Cooling Problems of Aircraft Engines. W. Worth. Paper discussing results of tests at the Material Division and Air Corps designs. Previously abstracted from preprint. (See DIGEST, April 1, page 35). S.A.E. Jour. (Trans.), July, 1937, pages 315–324, 12 illus., 2 equations.

Reports 40% Decrease in Aircraft Engine Weight. "Aircraft Engine Maintenance," by E. O. Cooper, and "Aircraft-Engine Installations," by I. L. Shogran. Brief abstracts of papers presented before the Southern California Section, and opinions expressed in the discussions following. S.A.E., July, 1937, page 27.

Engine Bearings

False Brinelling. J. O. Almen. Damaging of ball and roller bearings in automobiles, aircraft engines, and propellers during shipment in freight cars or trucks. Indentations occurred in bearing raceways opposite each of the balls or rollers on the loaded side of the bearings, and had the appearance of having been produced by extremely high pressures. M. Fink experimenting with an Amsler wear testing machine reached the conclusion that wear was due to formation and rubbing off of successive oxide films. Results obtained by Fink, G. A. Tomlinson, S. J. Rosenberg and L. Jordan, and S. A. McKee, E. A. Harrington, and T. R. McKee of the Bureau of Standards are discussed. Damages to an aircraft-engine rocker shaft bearing and to the main thrust bearing of a variable-pitch propeller are illustrated. To be continued. Automotive Industries, August 14, 1937, pages 226–228, 230, 6 illus.

New Test Engine Will Soon Be in Production. New cooperative universal single-cylinder engine designed to permit mounting of full-scale aircraft-engine cylinders and to be used in testing and developing aircraft and Diesel fuels and lubricants, spark plugs, gasoline- and Diesel-engine cylinders, piston rings, and accessories. Brief reference to engine designed by committee of the S.A.E. General Research Committee. S.A.E. August, 1937, page 28.

Engines

1500 Hp. Engine Given A.T.C. Wright 14-cylinder twin-row radial rated at 1200 hp. at 2100 r.p.m. at 5700 ft. pressure altitude and 1500 hp. at 2300 r.p.m. for the take-off. Few details. Western Flying, August, 1937, page 32.

Alvis Aircraft Engine. Two double-bank 18-cylinder radial engines, medium and fully supercharged, and rated at 1300 hp. and 1225 hp., respectively, and two double-bank 14-cylinder radial engines moderately and fully supercharged, respectively, and rated at 1000 hp. will be produced at the Alvis aircraft-engine factory in England for both civil and military aircraft. Test house of the new plant is equipped for testing engines up to 2500 hp. without inconveniencing the neighborhood by noise. Brief note. Automotive Industries, August 14, 1937, page 233.

The High Speed Diesel. A.E.C.—Ricardo and Perkins Diesel automobile engines. Few details and drawing of the combustion chamber of the Perkins, and references to the Ricardo. A brief note on the two-cylinder flat-twin 18-hp. Victor Diesel engine for airplanes is included. Les Ailes, June 17, 1937, pages 6–7, 1 illus.

New Régnier 60-Hp. Engine. New four-cylinder inverted inline aircraft engine. Long description. Les Ailes, May 6, 1937, page 8, 4 illus.

Technical Notes. First issue—New type of flat heavy-oil engine developed by M. Hébrard and composed of two banks of cylinders. Brief reference.

Second issue—Drawings illustrate the design of the Sklenar double rotary engine in which the French government is interested. It is said that Pratt and Whitney Company has purchased the license for this engine and that its research department has developed a 3000-hp. engine composed of three double-rotating radials joined together. Brief note. Les Ailes, April 29, and June 10, 1937, pages 7 and 7, 4 illus.

Air and Water. Bristol Pegasus XVIII has a two-speed supercharger, nine cylinders with a total capacity of 28.7 liters, and a take-off power of 980 b.hp. International rated power is 855 b.hp. at 5000 ft. using the medium supercharge ratio, and 800 b.hp. at 15,500 ft. using the full supercharge ratio. Few details and reference to three clutch units for changing supercharger speed. Engineer, August 6, 1937, page 153.

The Bristol Pegasus XVIII Aero Engine with Two-Speed Supercharger. The whole induction system has been designed to provide greater capacity, the induction pipe areas have been increased, and a new fully-automatic carburetor employing a three-stage automatic boost control and automatic mixture control have been added. Short note on 9-cylinder engine producing maxim power all out in level flight of 940 b.hp. at 6500 ft. and 900 at 17,750 ft. Engineering, August 13, 1937, page 180.

Bristol Sleeve Valve Engines. Technical and operational advantages of the sleeve valve, and long descriptions and photographs of the 9-cylinder Perseus and 14-cylinder two-row Hercules radial engines. The Perseus develops a maximum power of 860/890 hp. at 2750 r.p.m. at 7000 ft., and the Hercules 1325/1375 hp. at 2750 r.p.m. at 4000 ft. Characteristics of the Aquila 9-cylinder 500-hp. engine are given. Editorial also discusses the advantages of the sleeve valve. Aircraft Engineering, August, 1937, pages 218–222 and 203–204, 11 illus.

European Aviation Engines. Arthur Nutt. Paper previously abstracted from preprint. (See DIGEST April 1, page 38.) S.A.E., July, 1937 pages 13–18, 2 illus.

The Modern Trend. Latest Napier Dagger 108E aircraft engine. By an increase in the r.p.m. and the addition of a bigger supercharger, the power has been considerably increased beyond the previous output of 805 hp. at 4000 r.p.m. at 5000 ft. Captions of the photographs call attention to how the propeller drive has been raised and the overall length reduced to the new grouping of magneto and distributors in their screens, updraught carburetor, and small frontal area. Aeroplane, July 14, 1937, page 51, 3 illus.

A New Mercury. A 200-hour flying endurance test has been carried out on the new medium-supercharged Mercury XI motor rated at 790/820 hp. at 3500 ft. and having maximum power output of 890 b.hp. at 6000 ft. Few details of test results. Aeroplane, August 4, 1937, page 153.

Some New Ideas at Hatfield. Presence of so many airplane engines of over 1000 hp. was the most impressive thing about the static exhibition of the Society of British Aircraft Constructors. Output of 1700 hp. was for the Alvis Alcides. The most powerful type-tested engine was the British Hercules of which the medium supercharged version gives 1325/1375 hp. The most powerful liquid-cooled motor was the Rolls-Royce Merlin 1050 hp. The new Napier Dagger 108E has reduced length and higher output per liter than 49.7 hp. The smaller motors, especially the De Havilland Gipsy Major Series II, are referred to. Interesting points of De Havilland, Fairey, and Rotol propellers, Dowty's latest alighting gear, radio soreening harness, and riveting tools are illustrated and aircraft materials (including Perspex and bearings), and various instruments are reviewed. Aeroplane, July 7, 1937, pages 20–22, 21 illus.

The Swash-Plate Diesel. Sterling compact crankless opposed-piston two-stroke compression-ignition engine made in the United States is suggested for powering aircraft as it could be easily stowed inside the wing of a medium-sized airplane. Long description of engine. Aeroplane, July 21, 1937, pages 77–78, 4 illus.

The Walter Sagitta 500-Hp. Engine. Czechoslovakian twelve-cylinder inverted-vee aircooled engine develops 500 hp. at 2600 r.p.m. at 4100 meters and is designed for high-speed military airplanes. With a reduction gear which permits mounting of a cannon firing through the hub, the engine weighs only 395 kg. The Sagitta II RC, in which the supercharging is greater, develops 520 hp. at 4100 meters. Les Ailes, July 8, 1937, page 9, 1 illus.

Parts and Accessories

Arrangement of Superchargers on Foreign Aircraft Engines. W. von der Nuell. French piston supercharger for the Lorraine Petrel 500-hp. engine; a French crankcase supercharger; Roots superchargers for the Alfa-Romeo radial and Delage engines; Renault 1500 to 2000-hp. engine with double-flow supercharger inlet; Rolls-Royce supercharger drive; Rateau, Gnôme-Rhône, Pratt-Whitney, Renault and Rolls-Royce impellers; Rolls-Royce R engine with large supercharger; Lorraine Petrel 500-hp. engine with crankcase supercharger; Renault 300-hp. engine supercharger; supercharger drive of the Salmson 9-cylinder radial, Renault 12-cylinder 500-hp., and Hispano-Suiza 12-cylinder engines; Renault W 18-cylinder 700/830-hp. engine supercharger; Gnôme Rhône Jupiter, and Armstrong-Siddeley superchargers; Farman 520-hp. and 700-hp. engines; Curtiss Conqueror superchargers; Lorraine Eider 900-hp. engine; Napier Rapier H (300 hp. at 3000 m.); Wright Cyclone; Rolls-Royce Buzzard; Farman (many illustrations of parts); Renault 300-hp. with Rateau exhaust-gas turbo supercharger; newest Potez engine with exhaust-gas turbo supercharger; and the Moss turbine. Illustrations and descriptions. Luftwissen, June, 1937, pages 169–186, 60 illus.

A New Aircraft Carrier. "H.M.S. Indomitable," the 23,000-ton aircraft carrier, will be built by Vickers-Armstrong, Ltd. who are already building the "Illustrious" and "Victorius" 23,000-ton aircraft carriers. Brief reference. Aeroplane, July 28, 1937, page 108.

Royal Air Force Finance. A net surplus of the Exchequer grants for Air Services over the net expenditure for the year ended March 31, 1936 of £80,814 was announced in the House of Commons. Brief note. Aeroplane, July 28, 1937, page 109.

With the Flying Boats. An account of the R.A.F. Naval Exercises at Plymouth. Aeroplane, July 28, 1937, page 100.

Air Control of Aden. Practical experience in air control which the Royal Air Force is gaining in the Aden Protectorate. Note on events in which the R.A.F. participated as well as a brief account of a training flight which was made by five Vickers Vincents from Khartum to West Africa and back. Aeroplane, August 4, 1937, page 133.

Air Defence Exercises Limited. Due to a temporary shortage of trained R.A.F. personnel, the Exercises were designed to train inexperienced pilots and observers rather than commands and staffs. Few details. Aeroplane, August 11, 1937, page 161.

Air Ministry Contracts. List only of orders placed by the British Air Ministry during May. Aircraft Engineering, August, 1937, page 224.

The Coast Defence Exercises. C. M. McAlery. Problems affecting the three British Defence Services examined in the combined Coast Defence Exercises. For the first time the Exercises were controlled in part by a combined staff of all three services working from one operations room. Another important experiment was in the system of communications. Auxiliary services and, to a small extent, the civilian population, were also involved and during two nights the three undefended ports were blacked out. Long description. Aeroplane, July 21, 1937, pages 71–74, 9 illus.

Units taking part. Aeroplane, July 14, 1937, page 45.

Empire Air Day Accidents. Statement made in the House of Commons by Lt. Colonel Muirhead, Undersecretary of State for Air, on the subject of fatal accidents to R.A.F. personnel on Empire Air Day. Aeroplane, August 11, 1937, page 167.

Garrulousness. Questions asked in a debate in the House of Commons regarding export of high-powered engines and licenses to manufacture British military aircraft abroad. Aeroplane, July 7, 1937, page 2.

On the Fleet Air Arm. C. G. Grey. The Fleet Air Arm is under operational control of the Admiralty and administrative control of the Air Ministry but shore-based aircraft employed in cooperation with the naval forces is under Air Ministry operational as well as administrative control. Prime Minister's statement to the House of Commons, discussion taking place, and "The Daily Telegraph's" interviews with four retired Admirals are quoted. The author's comments include: controversy over the shore-based forces, the Fleet Air Arm of today and tomorrow, examples of how the Navy handled its affairs during the world war, the coastal patrol question, General William Mitchell's opinions, comparative costs of one battleship and 800 twin-motored airplanes. Aeroplane, August 11, 1937, pages 163–167.

On the Protection of the Empire. C. G. Grey. Comments on the recent debate in the House of Commons officially concerned with the salary of the Minister for the Co-Ordination of Defence, but touching rather on such points as food supply, bombproof-gasproof shelters, interweaving of the services, man power, waste of metals in parts of airplanes, and development of production of coal from oil. Quotations from the debate dealing particularly with defense from air attack. Aeroplane, August 4, 1937, pages 129–132.

The R.A.F. in India. Provision has been made for 250 officers and 1884 airmen for the R.A.F. in India. Brief reference. Aeroplane, July 14, 1937, page 37.

ITALY

Preparation and Participation of the Air Force of Italian East Africa in the Conquest of Ethiopia. General M. Aimone-Cat. Military operations are described. Abstract of paper presented before the Lilienthal Gesellschaft for Aeronautical Research. L'Aerotecnica, June, 1937, pages 535–536.

Expansion of the Independent Air Force, which now includes the greater part of the Air Force in Libya. Program provides for a strength of 93 wings with a regular personnel strength of 20,325 by January, 1941. Brief note. U.S. Naval Inst. Proc., July, 1937, page 1043.

JAPAN

Naval Summary. 4,200,000 pounds will be used for the expansion of Japanese naval aviation in the Japanese naval program for the next five years. Brief reference in an article discussing the naval program. U.S. Naval Inst. Proc., August, 1937, page 1191.

JUGOSLAVIA

Six Hawker Furys with Rolls-Royce Kestrel 16 engines and the licenses to produce them have been purchased by Jugoslavia. Brief reference. Les Ailes, July 29, 1937, page 5.

PHILIPPINES

Stearman Planes in Brazil and the Philippines. After completing its first year of operation, the Philippine Army Air Corps reports it has flown its three Stearman Model 73-L3 primary trainers a total of 1670 hours including 7619 separate leadings. Flying activities were carried on during 288 out of 307 week days of the twelve months. Brief references to this report and to a shipment of Stearman airplanes to Brazil. U.S. Air Services, August, 1937, page 37.

U. S. A.

Curtiss Awarded Contract. U. S. Army order for 230 Curtiss P-36 single-seater pursuits, and a few details of the airplane. Western Flying, August, 1937, page 32, 1 illus.

More Boeing Bombardment Planes for Army. Announcement of Secretary of War Woodring regarding award of a contract for ten more Boeing B-17 four-engined bombers, and referring to satisfactory results obtained with these airplanes. A second announcement in regard to the contract for 230 Curtiss P-36 pursuit airplanes, including a few details of the airplanes, is given in another article. U.S. Air Services, August, 1937, pages 14 and 16–17, 1 illus.

A Potential Pacific Air Gibraltar. Brig. Gen. W. E. Gillmore. Potentialities of Yerba Buena Island as a military airport with bomb-proof hangars deep in the rock are discussed. The site for San Francisco's new municipal airport will be used for the Golden Gate International Exposition during 1939. Brief reference is also made to the program of aerial defense in the San Francisco Bay Region. U.S. Air Services, August, 1937, pages 12–14, 1 illus.

Short Spans. Air Corps funds included in the recently approved Army Appropriations. Brief note on amounts for new airplanes. Western Flying, August, 1937, page 32.

Air Force Demonstration for War College. Demonstration of the fire power of modern aircraft for the benefit of the student body of Army War College on June 15 at Langley Field. Program and organizations stationed at Langley Field are discussed. Army Ordnance, September–October, 1937, page 103.

Field Service Problems. Lt. Colonel R. Marsh. Problem of ordnance service for aviation units, particularly the GHQ Air Force. Army Ordnance, September–October, 1937, pages 107–110.

Men or Material? Deficiencies which have seriously handicapped the effectiveness of the GHQ Air Force, and the increases in personnel and aircraft which are needed are discussed in an editorial on the military policy of the United States. Army Ordnance, September–October, 1937, pages 99–100.

Air Warfare

Colonial Seaplanes. Captain Gaudillère. Advantages of using seaplanes in defense of colonies are discussed, covering: numerous lakes and rivers available for alighting; missions of exploration, observation, cooperation with ground troops, heavy and light defense, and transportation; design requirements for such seaplanes; and types of bases needed. Rev. de l'Armée de l'Air, June, 1937, pages 629–646, 9 illus.

Firing in Pursuit and in Retreat During Aerial Combat. Brissot, Chief Engineer of Aeronautics. Comparison of firing in pursuit and firing in retreat, in regard to: hitting the adversary with a projectile having a certain minimum relative speed and having a given minimum speed; hitting when the time of flight of the projectile is fixed; superiority of firing in retreat; and the tactics of aerial combat. Criticism of articles by M. Odier and M. Garnier in the September, 1936, issue. Diagrams illustrate the priority of the fire from the fugitive plane. Rev. de l'Armée de l'Air, June, 1937, pages 607–608.

A Pass Defense for the Battle Line. Lt. Commander R. M. Ihrig. Peculiarities and tactical features of an anti-aircraft ship designed to protect a fleet from aircraft bombs. Recent reports indicate that the British Navy is considering an entirely new type of ship to be added to her fleet. In a second article entitled "Aerial Attacks on Fleets at Anchor," by Lt. Commander L. C. Ramsey is discussed strategical and tactical features of air attacks on fleets, indicating the hazard to ships is greater when anchored in a harbor and that the idea of the ideal naval base needs to be modified. U.S. Naval Inst. Proc., August, 1937, pages 1117–1121 and 1126–1132.

Some Hints on Air War. Experiences in the Spanish War have shown that when "moteur-canon" shells or machine-gun bullets hit a metal-covered wing, ripping it crosswise, the metal rips along the line of rivets but that the shells do less damage to fabric and plywood-covered wings. A new German bomber is said to carry 1000 small sprinkler bombs exploding by time fuse and dropped on enemy formations. A Swedish invention consists of spraying powder from a machine diving down in front of an enemy formation, thus setting fire to the enemy airplanes. Discussion of these rumors. Aeroplane, August 11, 1937, pages 155–156.

Armament. Military deficiencies of the multiplace "B.C.R." airplanes which have been proved in Spain, with special reference to the lack of coordinating operations between the gunners on the airplanes. Les Ailes, June 24, 1937, page 12.

War in Spain—Airplanes Against Ships. Commander H. P. Des Forges. Airplane bombing of ships with reference to the case of the Deutschland. Les Ailes, July 8, 1937, page 7.

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